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American Society of Farm Managers & Rural Appraisers

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 2025 issue of the *Journal of the ASFMRA*. These papers were selected following a rigorous peer-review process, and they cover a variety of relevant and timely topics including farm financial stress, carbon markets, and the impact of planter models on crop yield, just to name a few. The ASFMRA Editorial Task Force, and I trust that you will enjoy reading these papers as much as we did.

We have added a new feature to the *Journal* this year, which is an ASFMRA Annual Conference highlight. This issue’s first article summarizes a presentation from the Appraiser Rapid Fire Case Studies session, held last November at the 2024 ASFMRA Annual Conference in Kansas City. We look forward to future annual conference highlights in subsequent *Journal* issues.

Speaking of the Annual Conference, please be on the lookout for the *Journal* session at the 2025 ASFMRA Annual Conference in Clearwater, Florida. Two authors from this issue will be invited to present their papers, and we will recognize the 2025 Gold Quill Award winner for the most outstanding contribution to this year’s *Journal*. In the months ahead, please also be on the lookout for the first-ever ASFMRA Photo Contest, sponsored by the *Journal* and the ASFMRA Editorial Task Force. More details to follow!

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

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

Thank You to the 2024–25 Editorial Task Force

Table of Contents

Cultivating Precision: Integrating Generative AI into Rural and Agricultural Property Valuation

By Jim Amorin, CAE, MAI, SRA, AI-GRS, CDEI, ASA

Jim Amorin, MAI, SRA, AI-GRS, CDEI, CAE, ASA, has been engaged in the real estate appraisal and consulting arena since 1988. He recently authored the seminal text *The Generative Shift: Preparing Appraisers for Artificial Intelligence Models like ChatGPT* (2024). This article is a summary of his ASFMRA Annual Conference Appraiser Rapid Fire Case Study presentation, delivered in Kansas City, MO, in November 2024.

INTRODUCTION

The landscape of real estate appraisal is shifting, and artificial intelligence (AI) is at the heart of this transformation. At the recent ASFMRA conference, my session explored how generative AI is reshaping the valuation of rural and agricultural properties, challenging traditional methodologies, and equipping appraisers with new tools for enhanced precision and efficiency.

FROM TRADITION TO TRANSFORMATION

For decades, real estate appraisals relied on manual processes, paper-based reports, and expert judgment. However, as markets become more complex and clients demand faster, more accurate insights, AI-driven tools offer a significant advantage. My session emphasized that AI is not about replacing appraisers but empowering them by automating routine tasks, refining data analysis, and uncovering deeper market trends that would be difficult to detect using conventional methods.

PRACTICAL APPLICATIONS AND CASE STUDIES

A key focus of the presentation was demonstrating real-world applications of AI in rural and agricultural valuation. We examined AI-powered market condition adjustments, where large language models (LLMs) help extract pricing trends from datasets with greater speed and accuracy. A custom-built price indexing tool illustrated how AI can identify temporal price shifts using regression models, an invaluable capability for appraisers working in dynamic markets.

We also explored how AI-enhanced data analysis can quantify the value of specific property characteristics, such as mountain views, proximity to parks, and topographic challenges. By running multiple regression analyses on real-world datasets, AI models revealed statistically significant value premiums for desirable attributes while quantifying discounts for less favorable factors. These case studies underscored the potential of AI to supplement, rather than supplant, appraiser expertise.

AI IN AGRICULTURE: BEYOND VALUATION

The session extended beyond traditional real estate to showcase AI's growing role in agricultural technology. From AI-driven precision weed spraying to computer vision applications in crop monitoring, yield estimation, and livestock management, the broader implications of AI in rural land use were evident. These technologies not only enhance agricultural productivity but also shape land valuation by influencing factors such as soil quality, crop viability, and operational efficiencies.

ETHICAL CONSIDERATIONS AND THE ROLE OF THE APPRAISER

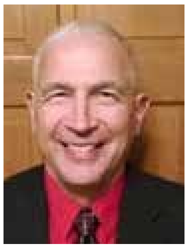
With great power comes great responsibility, and AI in appraisal is no exception. The session addressed the risks of AI-generated inaccuracies—commonly known as "hallucinations"—and the importance of rigorous verification. Appraisers must adhere to ethical standards, ensuring AI is used transparently and in compliance with regulatory frameworks such as USPAP. The discussion reinforced that while AI is a powerful tool, human judgment remains irreplaceable.

THE ROAD AHEAD

The key takeaway from the session? AI is not a threat to appraisers—it's a tool that, when wielded effectively, can enhance accuracy, streamline workflows, and unlock new insights. As AI adoption accelerates, appraisers who embrace these technologies will find themselves better equipped to navigate an increasingly complex valuation landscape.

The overwhelmingly positive response from attendees confirms that AI's role in rural and agricultural property valuation is a topic of growing importance. With thoughtful integration and ethical oversight, AI is poised to become an indispensable asset in the appraiser's toolkit.

A Case Study Measuring Solar Array Impacts on New York Residential Values



By Donald A. Fisher

Donald A. Fisher is the Valuations Services Director at Colliers Valuation and Advisory Services in Upstate New York.

Abstract

Solar energy production has exploded on rural and suburban United States tracts of land within the past two decades, gobbling up thousands of acres of land for ground-mounted arrays of photovoltaic panels. Some solar farms exceed capacities of 500 megawatts and cover thousands of acres. One of the most common concerns with proposed solar farm development is the potential for adverse impacts on nearby residential property values. This case study examines one process for measuring changes in residential property values near solar farms. Additional questions addressing environmental concerns, livestock grazing, and possible mitigation measures are also identified. Appraisers from other regions can follow the analysis format in this paper to develop relevant studies that analyze impacts on residential property prices as well as to identify other areas of concern that may be applicable for proposed solar farm development. This paper is intended to provide the reader with some options of how to analyze and measure the impact that a large solar array may have on surrounding property values. This author was one of the presenters of the "Impact of Solar on Rural Property Values" webinar presented by ASFMRA in August 2022. The presentation reviewed the procedures that this appraiser used to evaluate the impact on residential properties near established solar farms throughout Upstate New York. Market studies completed for this purpose were usually commissioned by solar farm developers or the local municipalities and had intended uses to analyze this type of impact in mostly rural and suburban locations.

INTRODUCTION

The United States' rural landscape has been undergoing a significant change over the past two decades, with the substantial growth in solar energy production at an overall annual growth rate of 25% over the past decade. This is evident by a high volume of ground-mounted photovoltaic (PV) arrays commonly known as PV power stations, solar farms, solar parks, or solar power stations. Solar is a renewable type of power generation serving to supplement fossil fuel or nuclear energy generating plants that have existed for decades. According to the U.S. Energy Information Administration, the U.S. solar industry installed 32.4 gigawatts (GW) of capacity in 2023, which was a 51% increase from 2022 and the industry's largest year ever.

Solar energy accounted for 5.6% of the country's electricity generation in 2023, up 4.8% from 2022. Solar accounted for 15.9% of electricity generated by renewable sources in 2022, up from 13.5% in 2021. Based on the new solar projects planned for the next two years, the forecast is that the U.S. solar power generation will grow 75% from 163 billion kilowatt hours (kWh) in 2023 to 286 billion kWh in 2025.

Solar farms differ from smaller-scale rooftop residential and commercial systems, which usually are designed to provide electrical power to single buildings. The size of solar farms allows those installations to benefit from economies of scale not found in the smaller applications, where a single solar farm location can include thousands to tens of thousands of panels compared to a few dozen panels in the smaller installations.

From the national solar farm database, there have been over 7,500 active projects developed in the past 20 years, with research and development having steadily progressed and advanced over these two decades. The Solar Energy Industries Association (SEIA) and Wood MacKenzie (publisher of US Solar Market Insight) expect the U.S. solar industry to install approximately 40 gigawatts-direct current (GWdc) in 2024, which would constitute over 60% of all new U.S. electricity generation in 2024. SEIA is leading the transformation to a clean energy economy by helping to create a framework for solar to achieve 30% of total U.S. electricity generation by 2030.

In many states, solar farms now cover tens of thousands of acres of land, with the larger solar farms each covering hundreds to a thousand or more acres. Industrial-scale solar farms can have over 1 million separate solar panels. Utility-scale solar development in rural areas has been getting a lot of attention for more than a decade, both from landowners interested in leasing land and, conversely, from those who oppose solar farm projects for a variety of reasons including competition for vacant open land and for potential impacts on nearby property values.

Solar farms have been identified as the new “cash crop” because financial returns from land rentals for solar panels are often significantly higher than historic rental rates for crop land and pastureland. Solar leases are viewed as windfalls by rural landowners who historically have rented to neighboring dairy, livestock, and crop farm owners for typically substantially lower rental rates. However, losing rented cropland and pastureland can be devasting to those same dairy and livestock farm operations because it can lead to drastic changes in herd size to remain in compliance with Concentrated Animal Feeding Operation requirements set by the Environmental Protection Agency for large dairy and livestock farms. Significant drops in rented land for crop farm operations can affect economies of scale relative to equipment, machinery, seed, fertilizer, etc., purchases along with the numbers of employees required.

This case study will not address the economic impact that solar farms have on the agricultural industry by the removal of tillable acreage from crop production, which is recognized as a major concern. Rather, this case study will be limited to analyzing the possibility of adverse impacts on nearby residential property values.

Solar developers, municipalities, and property owners have been seeking market evidence regarding the impact of proposed solar farms on the value of nearby properties, if the solar farms would be in harmony with the neighborhood, and what actions could be taken to minimize or erase any potential negative impacts on surrounding property values.

Many municipalities that permit solar farm development require an extensive application and approval process that often includes a study on the impact that a large array of solar panels could have on surrounding residential property values. Often these studies are presented at public hearings and could involve expert witness testimony from a consultant who has prepared a value impact analysis. This paper will outline different types of analyses that can be compiled into a market study to show trends in residential property prices between the periods prior to and after the construction of a large-scale solar array.

Some of the questions posed by municipalities and surrounding property owners can be answered with a series of market studies that analyze the sale prices of surrounding improved properties near recently constructed PV solar panel ground-mounted arrays.

MARKET RESEARCH: BEFORE AND AFTER SALES ANALYSIS

Based on this author’s experience, owners of single-family residential properties represent the market sector most interested and/or concerned about the impact of a new solar farm in their neighborhood. Single-family residences are also the most common improved property type that typically transfer in the open market at somewhat regular frequencies. As such, it is also the most logical property type to use in measuring changes in values over a select time period.

The scope of work for these market studies includes the application of part of the Sales Comparison

Approach, which consists of research and statistical analysis of completed transfers of improved residential properties. Sale prices of residential properties within proximity of identified solar farms for the period prior to the public notice of the solar farm project are compared to the sale prices of residential properties in the same area that occurred after the commissioned date when each respective solar farm's construction was completed. Sales prices are reduced to unit prices (price per square foot of building area) to reduce the need for adjustments. The research and analysis that is summarized in this paper has been compiled from studies completed throughout Upstate New York.

There are multiple databases available for this type of research. In New York State, some of the common databases are Real-Info, ImageMate, and the Multiple Listing Service. The New York State Energy Research and Development Authority maintains a database of all PV arrays constructed in the state, ranging from small rooftop solar panels to the large ground-mounted arrays. This database includes the Public Notice/Application Data and the Commissioned/Completion Data of each identified commercial solar farm that can be used to establish the "before and after" dates for sales research.

The solar farm sites analyzed in these market studies were identified from various databases where information on location, size, public notice, and commissioned dates could be determined. One of the parameters included in the selection of solar farm sites is the availability of commissioned and completion dates far enough in the past to allow for a sufficient period of time for sales of improved residential properties in close proximity to the solar farm sites to have occurred for analysis purposes. The period after the commissioned date should be at least one to two years so that there is a sufficient time period for the local market to react to the presence of a new solar farm and for market research in the "after" period.

A series of market studies can be conducted to measure changes in single-family residential sale prices before and after the construction of existing solar farms. Suggested parameters to use for these market studies include:

- Identify locations of recently constructed solar farms
- Identify the application and commissioned or completion dates of those solar farms
    - The period from initial application until the solar farm has been constructed should be identified and excluded from the "before and after" study periods to avoid market data that might be affected by short-term effects (similar to the concept of a "before and after" appraisal analysis for eminent domain appraisals)
- Identify a one- to two-year period prior to the commissioning date for the ***before-study*** period and a one- to two-year period after the completion date for the ***after-study*** period
    - The time period chosen can vary depending upon the number of transfers available to use for statistical analysis, for example, ranging from six months to two years, depending upon the number of usable transfers
    - Compiling multiple sales of similar house styles may require longer study periods
- Identify a radius around each solar farm being studied to collect sales
    - Few sales and/or distant viewsheds may require larger study areas
    - A high number of sales and/or short viewsheds may permit smaller study areas
    - Buyers that may have paid opt-in premiums to use or buy electricity from the new solar farm should be excluded to preserve an objective market's perspective of the impact of the solar farm
- Research databases for residential sales in each period
    - Arm's length conditions
    - Identify sale date, sale price, house size, house age, house style, land area
    - Identify transactional details including seller, buyer, sale date, sale price
    - For each set of sales, calculate average and median house sizes and average and median sale prices
    - Calculate overall average and median price per square foot
        - Using unit sale prices will tend to average out the variations in house size, style, and other features
        - Average and median unit prices are universally accepted units of comparison for many types of improved properties
    - Analyze the time trend between the mid-point of the ***before*** sales and the ***after*** sales

and apply that to the ***before*** sales to show the time-adjusted unit prices as of the mid-point of the ***after*** sales

    - Using unit sale prices will tend to average out the variations in house size, style, and other features
    - Develop a time trend analysis for the location of each solar farm being studied
    - Use midpoint of each time period to trend the before sale unit prices to the after-sale unit prices

- Consider other significant adjustments
    - Compare average and median house sizes between the two sets of sales; if the average and/or median house sizes are over 100 square feet different, then use a size-to-unit price adjustment; for example, Marshall Valuation Service [MVS] publishes Floor Area Multipliers that can be used to adjust for significant differences in building sizes
    - Limiting site sizes to what is typical in the area, say, in the <1.0- to 3.0-acre range, will usually eliminate large discrepancies in average and median site sizes, helping to ensure that the data sets are relatively uniform
    - Reviewing the individual sale prices to cull transactions that obviously show atypical conditions to create more reliable data sets

The appraiser should consider completing market studies on a minimum of four to five existing solar farms so that trends in sale prices and outliers can be extracted from the market data. If there are several sales of the same house type (e.g., ranch, raised ranch, cape cod, colonial, contemporary) in both the ***before*** and ***after*** data sets, the subsets of before and after residential sales can also be considered to see if owners of specific house styles react significantly differently from other house style owners.

The ***before*** and ***after*** sale data sets can also be checked to see if the same property sold both before and after the construction of a solar farm being studied. While it is recognized that some renovations may have been completed during the interim period, comparing the before and after prices, after adjusting for local appreciation, can provide additional market evidence of the impact of a solar farm on nearby residential prices.

A review of the before and after sales may reveal transactions of the same property that can serve as a subset of the before and after sales analysis to see if the second buyer of the same residence paid an appreciated price or a price that was lower than the area time trend indicates. Unfortunately, without investigating the condition of the residential property at the time of the two transactions to see if remodeling, renovation, expansion, or other significant changes had occurred during the interim time period, an analysis of sale/resale transactions can be skewed.

A series of tables demonstrate before and after sale price analyses for areas surrounding established solar farms. The full Excel table compiled for an actual assignment will include assessor parcel number, street address, town, school district, seller, buyer, deed book and page, and other relevant information. The sales research for this specific study included parameters of a maximum five-acre site and minimum $50,000 sale price. Table 1 is the Building Size Adjustment table from the Marshall Valuation Services manual. The next three tables are examples of a before and after sales analysis, where Table 2 shows the sales of all house styles in the study area, and Tables 3 and 4 showing reduced sets of sales for two specific house styles.

ADDITIONAL MARKET FACTORS

Some municipalities require evidence from other market gauges applicable to solar farm impacts that could include stigma; perceptions of odor, noise, and pollution; market perceptions of the development of solar farms; and even market value enhancement. The consultant may be requested to discuss and/or analyze some or all of the following impacts.

Harmony of Use and Compatibility

Are solar farms compatible with traditional rural and suburban land uses? Large solar farms are usually in rural areas dominated by agricultural and recreational land with scattered rural residences. Farms and houses often range from one to two stories in height, varying from 15 to 35 feet high, with silos and grain bin complexes often 35 feet or taller. Trees typically will grow to 40 to 60 feet or more. Ground mounted solar arrays usually are not higher than 12 to 15 feet above the ground. Solar farms are commonly not the tallest structures in a neighborhood because the viewshed is usually broken by other buildings and trees.

Solar farms in urban and suburban areas are usually smaller because available tracts of land for PV array projects are generally smaller parcels. These neighborhoods are mixes of residences, commercial, industrial, and institutional buildings, some of which have greater heights and variety in building styles where solar farms will be less noticeable from distances that are more than one to two blocks. Research should include the characteristics of the neighborhood surrounding the proposed solar farm and whether solar panels would be incompatible with existing buildings and tree cover.

Figures 1 and 2 show examples of existing farm building complexes with heights greater than ground-mounted solar arrays.

Hazardous Material Concerns

The components of a solar panel include solar PV cells, toughened glass, extruded aluminum frame, encapsulation, polymer rear back-sheet, and junction box containing diodes and connectors. Solar panels use PV cells made from silicon crystalline wafers like those used to make computer processors. The silicon wafers can be either polycrystalline or monocrystalline and are produced via several different manufacturing methods. The components are contained within sealed boxes with glass covers that do not leak, spill, drip, or otherwise allow components to seep out of the sealed compartment. If the panel units are monitored for condition for cracks or glass breakage, such as from hailstorms or vandalism, hazardous material leakage shouldn't be a problem. Research should include investigating the history of the solar developer's operations at other existing sites to determine if regular monitoring is standard operating procedure.

Appearance

Large solar farms occupy tracts of land ranging from a few dozen acres to 100+ acres, with industrial-scale arrays exceeding 1,000 acres. Fixed solar panels on ground racks are usually less than 15 feet high, less than the typical height of a single-story residential, commercial, industrial, agricultural, or institutional building. Large farms have big building complexes such as dairy, poultry, hog, and horse barns, or commercial greenhouses, all which are taller than a solar ground-mounted array. Do these types of improvements already exist near the proposed site?

The appearance of a well-manicured farmstead can be aesthetically appealing to neighbors and passers-by, but an unkempt farmstead with untrimmed landscaping, unpainted and/or poorly maintained buildings, and scattered machinery could have the opposite effect. Large expanses of solar panels could be aesthetically unattractive, but if the viewshed is interrupted with vegetative barriers or changes in the terrain, the negative appearance could be minimized or eliminated.

Stigma

Stigma in real estate applies to a property that is shunned by buyers or tenants for reasons that are unrelated to its physical condition or features, such as death of an occupant, murder, suicide, serious illness, or claimed hauntings and paranormal activity. Stigma can also refer to proximity to socially unacceptable or undesirable real property uses such as junkyards, prisons, adult entertainment establishments, livestock farms (with odors and noises), wetlands (with odors and insects), industrial facilities (noise, odor, activity), and even schools (game fields with light pollution and noise in the evenings). Solar farms do not have any of these characteristics, being passive uses of the land that do not require daily human interaction or artificial lighting, make no noticeable noise, and emit no odors. The human interaction element is usually limited to weekly to monthly inspections for maintenance, vegetation trimming, and/or livestock monitoring.

Odor

As already established, solar panels are self-contained units that operate passively and emit no odor.

Noise

Solar panels do not produce any noise except for a barely audible whisper during daylight hours that can only be heard if standing next to the panels. The transformers often have a humming sound that is like the hum of fluorescent lights used in office buildings, residential garages and basements, barns, and industrial buildings. Municipalities will usually require that a solar farm has a buffer of 100 feet or more between the property boundary and the nearest panels, where these humming sounds cannot be heard from off-site locations. Adding the front, side, and/or rear setbacks usually required for surrounding residences, the nearest homes are usually at least 200 feet or more from the nearest solar panels. No sounds are emitted from the solar equipment at night because no solar energy is being converted to electricity during periods when the sun is not shining. If battery storage occurs on the site of a solar farm, the batteries usually do not omit any noise with higher decibels than the transformers.

Reflection or Glare off Panels

The top of a solar panel is comprised of one or more layers of glass, with the top layer typically high-strength tempered glass that is 3.0- to 4.0-mm thick and designed to resist mechanical loads and extreme temperature changes. Obviously, the glass is also transparent to permit sunlight penetration to the PV cells. Like most types of glass, sunlight will reflect off the solar panels, which is most noticeable during early mornings and late afternoons when the sun is at the greatest angle to the solar panel surfaces. Reflection may be noticed but is often disrupted by trees and/or distance. And due to the movement of the sun, any reflections are usually temporary and shifting across the land.

Traffic

On-site traffic for established solar farms is often at frequencies of about once per month. Such traffic could be for lawn mowing or monitoring and performing maintenance on the equipment. This rate of on-site traffic is significantly less than what would occur for residential uses (multiple trips per day), agricultural uses (ranging from daily activities around the buildings and pasture lands to a few times per growing season), commercial and industrial uses (multiple times per day, some possibly including large trucks and machinery), and institutional uses such as schools (multiple times per school day or during school activities, with activity ranging from bicycles, cars and pickups, school buses, and delivery trucks). Therefore, the impact of traffic affiliated with a solar farm is significantly less than what would be expected for almost any other type of use that could be developed on the land.

Livestock Pasturing

A relatively new trend for solar farms is to lease or sublease the land that the solar panels are on to sheep farms for pasturing purposes. Some types of livestock such as cows, horses, and goats could damage the solar panels by attempting to mount or climb up the sloping panels, but sheep are one type of livestock that doesn't climb in that fashion. Sheep are naturally suited to grazing under solar panels because of their low height and preference to graze in places humans would struggle to reach. Using solar farms for pastureland reduces the number of visits to the project for lawn-mowing purposes, but there could be short periods of truck activity at the beginning and end of the pasturing period as the sheep are moved in and taken away.

Distance between Homes and Solar Panels

Most municipalities require a minimum of 100 feet between the solar panels and the property boundaries. When considering road widths of 50 to 70 feet and front yard setbacks of 75 feet or more, very few residences are closer than 200 feet from the nearest solar panels of a solar farm.

Landscaping

Some municipalities require a landscape buffer between the solar panels and the surrounding residential properties. These buffers can consist of a combination of earthen berms topped with trees to offsetting rows of trees two to three trees thick, which can include a row of low-growing shrubs to create a natural barrier screening the solar farm from nearby residences.

Realtors, residential appraisers, and assessors can be interviewed to find out the extent of their knowledge and experiences from any observations about adverse changes in the residential prices near ground-mounted solar farms after they've been constructed.

CONCLUSION

A variety of market research and/or market investigation is available to analyze the reactions of buyers and sellers of residential properties around existing PV solar arrays that can be used to project the changes in residential prices for a proposed solar farm. The researcher may also consider additional factors such as the possibility of hazardous material, appearance, stigma, odor and noise, on-site traffic, landscaping buffers, and commentary from real estate professionals including realtors, residential appraisers, and assessors. The combination of these market measurements can be used to determine if any characteristics of a proposed solar farm could potentially adversely affect residential values in the solar farm's neighborhood.

Figure 1. Greenhouse complexes

Figure 2. Dairy farm barn complex (left) and poultry farm barn complex (right)

Table 1. Marshall Valuation Services Building Size Adjustments

Single-Family Residence Size Adjustments																
Bldg SF	MVS Area Multiplier	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
1000	1.040	**0.000**	-0.009	-0.018	-0.026	-0.033	-0.040	-0.046	-0.052	-0.058	-0.063	-0.068	-0.072	-0.077	-0.081	-0.085
1100	1.031	0.009	**0.000**	-0.009	-0.017	-0.024	-0.031	-0.037	-0.043	-0.049	-0.054	-0.059	-0.063	-0.068	-0.072	-0.076
1200	1.022	0.018	0.009	**0.000**	-0.008	-0.015	-0.022	-0.028	-0.034	-0.040	-0.045	-0.050	-0.054	-0.059	-0.063	-0.067
1300	1.015	0.026	0.017	0.008	**0.000**	-0.008	-0.014	-0.021	-0.027	-0.033	-0.038	-0.043	-0.047	-0.051	-0.055	-0.060
1400	1.007	0.033	0.024	0.015	0.008	**0.000**	-0.007	-0.013	-0.019	-0.025	-0.030	-0.035	-0.039	-0.043	-0.048	-0.052
1500	1.001	0.040	0.031	0.022	0.014	0.007	**0.000**	-0.007	-0.013	-0.019	-0.024	-0.029	-0.033	-0.037	-0.041	-0.046
1600	0.994	0.046	0.037	0.028	0.021	0.013	0.007	**0.000**	-0.006	-0.012	-0.017	-0.022	-0.026	-0.031	-0.035	-0.039
1700	0.988	0.052	0.043	0.034	0.027	0.019	0.013	0.006	**0.000**	-0.006	-0.011	-0.016	-0.020	-0.025	-0.029	-0.033
1800	0.982	0.058	0.049	0.040	0.033	0.025	0.019	0.012	0.006	**0.000**	-0.005	-0.010	-0.014	-0.019	-0.023	-0.027
1900	0.977	0.063	0.054	0.045	0.038	0.030	0.024	0.017	0.011	0.005	**0.000**	-0.005	-0.009	-0.014	-0.018	-0.022
2000	0.972	0.068	0.059	0.050	0.043	0.035	0.029	0.022	0.016	0.010	0.005	**0.000**	-0.004	-0.009	-0.013	-0.017
2100	0.968	0.072	0.063	0.054	0.047	0.039	0.033	0.026	0.020	0.014	0.009	0.004	**0.000**	-0.004	-0.009	-0.013
2200	0.964	0.077	0.068	0.059	0.051	0.043	0.037	0.031	0.025	0.019	0.014	0.009	0.004	**0.000**	-0.004	-0.009
2300	0.959	0.081	0.072	0.063	0.055	0.048	0.041	0.035	0.029	0.023	0.018	0.013	0.009	0.004	**0.000**	-0.004
2400	0.955	0.085	0.076	0.067	0.060	0.052	0.046	0.039	0.033	0.027	0.022	0.017	0.013	0.009	0.004	**0.000**

Table 2. All House Sales within Case Study Area

XXX SOLAR FARM (COMPLETED AUGUST 2020) ALL HOUSE STYLES						
STREET	**BLDG SF**	**HOUSE STYLE**	**ACRES**	**SALE DATE**	**SALE PRICE**	**PRICE PER BLDG SF**
POLLARD HILL RD	1,728	COLONIAL	0.92	2018-05-04	$278,350	$161.08
POLLARD HILL RD	1,482	CAPE COD	1.30	2018-09-14	$155,000	$104.59
KING HILL RD	1,417	CONTEMPORARY	2.50	2018-10-26	$125,000	$88.21
E MAINE RD	1,176	OLD STYLE	1.15	2018-11-21	$142,500	$121.17
KOLB RD	1,440	RAISED RANCH	2.32	2018-11-29	$60,000	$41.67
TIONA RD	2,016	CAPE COD	1.27	2018-12-17	$60,000	$29.76
MCGREGOR AVE	787	OLD STYLE	0.42	2019-02-15	$60,000	$76.24
NANTICOKE RD	988	RANCH	0.29	2019-03-19	$94,000	$95.14
LEWIS ST	1,404	CAPE COD	1.44	2019-06-14	$128,865	$91.78
TIONA RD	1,298	RAISED RANCH	2.39	2019-07-19	$136,000	$104.78
CHURCH ST	1,741	OLD STYLE	0.60	2019-08-30	$97,500	$56.00
CHURCH ST	1,200	OLD STYLE	1.50	2019-10-22	$130,000	$108.33
AVERAGE	**1,390**		**1.34**		**$122,268**	**$87.98**
MEDIAN	**1,411**		**1.29**		**$126,933**	**$89.99**
AVERAGE		**1.000**	**HOUSE SIZE ADJUSTMENT - AVERAGE**			**$87.98**
MEDIAN		**1.000**	**HOUSE SIZE ADJUSTMENT - MEDIAN**			**$89.99**
TOTAL TIME TREND		**12.5%**	**TIME-ADJUSTED AVERAGE**			**$98.98**
			TIME-ADJUSTED MEDIAN			**$101.24**

Continued on next page

Table 2. All House Sales within Case Study Area (Continued)						
XXX SOLAR FARM (COMPLETED AUGUST 2020) ALL HOUSE STYLES						
STREET	BLDG SF	HOUSE STYLE	ACRES	SALE DATE	SALE PRICE	PRICE PER BLDG SF
LUDINGTON ROAD EXT	1,861	CAPE COD	2.00	2020-10-03	$225,000	$120.90
STATE ROUTE 26	884	RANCH	0.60	2020-10-22	$124,600	$140.95
ST ROUTE 26 AVE	1,704	OLD STYLE	0.36	2020-11-02	$85,000	$49.88
STATE ROUTE 26	2,064	OLD STYLE	1.51	2020-12-30	$90,000	$43.60
NANTICOKE RD	2,072	RAISED RANCH	4.73	2021-01-26	$186,000	$89.77
OLD NANTICOKE RD	764	RANCH	1.26	2021-02-04	$138,127	$180.79
MAPLE AVE	1,050	OLD STYLE	0.27	2021-06-28	$118,173	$112.55
LEWIS ST	1,400	RANCH	0.27	2021-07-27	$133,500	$95.36
LEWIS ST	1,314	OLD STYLE	0.65	2021-07-29	$50,000	$38.05
EAST MAINE RD	1,032	RANCH	1.84	2021-08-31	$152,000	$147.29
NANTICOKE RD	1,501	RANCH	1.00	2021-09-03	$185,000	$123.25
LEWIS ST	1,043	OLD STYLE	2.42	2021-10-27	$82,000	$78.62
STATE ROUTE 38B	960	RANCH	0.93	2021-11-02	$50,000	$52.08
SHERDER RD	1,506	RANCH	0.94	2021-11-19	$200,000	$132.80
HARDY RD	2,124	OLD STYLE	1.00	2021-12-07	$52,000	$24.48
KOLB RD	1,008	RANCH	3.40	2022-03-16	$145,000	$143.85
STATE ROUTE 26	1,892	RAISED RANCH	2.86	2022-03-18	$195,000	$103.07
STATE ROUTE 38B	960	RANCH	0.93	2022-06-14	$124,550	$129.74
MAPLE AVE	2,392	OLD STYLE	0.58	2022-07-25	$195,000	$81.52
E MAINE RD	1,092	RANCH	0.62	2022-08-04	$150,000	$137.36
POLLARD HILL RD	1,818	CONTEMPORARY	1.48	2022-08-24	$270,000	$148.51
POLLARD HILL RD	1,852	RAISED RANCH	1.39	2022-08-31	$195,000	$105.29
LEWIS ST	1,192	RAISED RANCH	0.91	2022-09-29	$95,000	$79.70
TIONA RD	1,298	RAISED RANCH	2.39	2022-10-31	$172,000	$132.51
POLLARD HILL RD	1,728	COLONIAL	0.92	2022-10-31	$376,000	$217.59
STATE ROUTE 26	1,405	OLD STYLE	0.33	2022-11-04	$92,597	$65.91
ASHLEY RD	1,008	RANCH	1.88	2022-11-09	$115,000	$114.09
STATE ROUTE 26	1,842	OLD STYLE	1.95	2022-12-08	$110,000	$59.72
AVERAGE	**1,456**		**1.41**		**$146,662**	**$100.73**
MEDIAN	**1,403**		**1.00**		**$135,814**	**$96.84**

VALUE CHANGE FROM BEFORE SALES	**AVERAGE**		**1.78%**
	MEDIAN		**-4.35%**

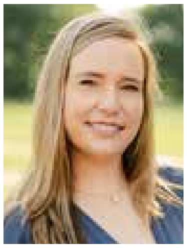
Table 3. Old Style House Sales within Case Study Area

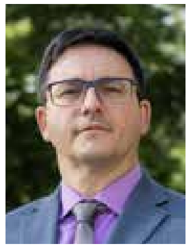
XXX SOLAR FARM (COMPLETED AUGUST 2020) OLD STYLE HOUSE STYLES						
STREET	**BLDG SF**	**HOUSE STYLE**	**ACRES**	**SALE DATE**	**SALE PRICE**	**PRICE PER BLDG SF**
E MAINE RD	1,176	OLD STYLE	1.15	2018-11-21	$142,500	$121.17
MCGREGOR AVE	787	OLD STYLE	0.42	2019-02-15	$60,000	$76.24
CHURCH ST	1,741	OLD STYLE	0.60	2019-08-30	$97,500	$56.00
CHURCH ST	1,200	OLD STYLE	1.50	2019-10-22	$130,000	$108.33
AVERAGE	**1,226**		**0.92**		**$107,500**	**$87.68**
MEDIAN	**1,188**		**0.88**		**$113,750**	**$95.75**
AVERAGE		**0.972**	**HOUSE SIZE ADJUSTMENT - AVERAGE**			**$85.23**
MEDIAN		**0.966**	**HOUSE SIZE ADJUSTMENT - MEDIAN**			**$92.49**
TOTAL TIME TREND		**12.5%**	**TIME-ADJUSTED AVERAGE**			**$95.88**
			TIME-ADJUSTED MEDIAN			**$104.06**
ST ROUTE 26 AVE	1,704	OLD STYLE	0.36	2020-11-02	$85,000	$49.88
STATE ROUTE 26	2,064	OLD STYLE	1.51	2020-12-30	$90,000	$43.60
MAPLE AVE	1,050	OLD STYLE	0.27	2021-06-28	$118,173	$112.55
LEWIS ST	1,314	OLD STYLE	0.65	2021-07-29	$50,000	$38.05
LEWIS ST	1,043	OLD STYLE	2.42	2021-10-27	$82,000	$78.62
HARDY RD	2,124	OLD STYLE	1.00	2021-12-07	$52,000	$24.48
MAPLE AVE	2,392	OLD STYLE	0.58	2022-07-25	$195,000	$81.52
STATE ROUTE 26	1,405	OLD STYLE	0.33	2022-11-04	$92,597	$65.91
AVERAGE	**1,637**		**0.89**		**$95,596**	**$58.40**
MEDIAN	**1,555**		**0.62**		**$87,500**	**$56.29**
VALUE CHANGE FROM BEFORE SALES				**AVERAGE**		**-39.09%**
				MEDIAN		**-45.91%**

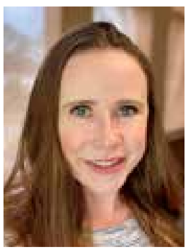
Table 4. Ranch House Sales within Case Study Area

XXX SOLAR FARM (COMPLETED AUGUST 2020) RANCH HOUSE STYLES						
STREET	**BLDG SF**	**HOUSE STYLE**	**ACRES**	**SALE DATE**	**SALE PRICE**	**PRICE PER BLDG SF**
NANTICOKE RD	988	RANCH	0.29	2019-03-19	$94,000	$95.14
AVERAGE	**988**		**0.29**		**$94,000**	**$95.14**
MEDIAN	**988**		**0.29**		**$94,000**	**$95.14**
AVERAGE		**0.991**	**HOUSE SIZE ADJUSTMENT - AVERAGE**			**$94.29**
MEDIAN		**1.000**	**HOUSE SIZE ADJUSTMENT - MEDIAN**			**$95.14**
TOTAL TIME TREND		**12.5%**	**TIME-ADJUSTED AVERAGE**			**$106.07**
			TIME-ADJUSTED MEDIAN			**$107.03**
STATE ROUTE 26	884	RANCH	0.60	2020-10-22	$124,600	$140.95
LEWIS ST	1,400	RANCH	0.27	2021-07-27	$133,500	$95.36
EAST MAINE RD	1,032	RANCH	1.84	2021-08-31	$152,000	$147.29
NANTICOKE RD	1,501	RANCH	1.00	2021-09-03	$185,000	$123.25
STATE ROUTE 38B	960	RANCH	0.93	2021-11-02	$50,000	$52.08
SHERDER RD	1,506	RANCH	0.94	2021-11-19	$200,000	$132.80
KOLB RD	1,008	RANCH	3.40	2022-03-16	$145,000	$143.85
STATE ROUTE 38B	960	RANCH	0.93	2022-06-14	$124,550	$129.74
E MAINE RD	1,092	RANCH	0.62	2022-08-04	$150,000	$137.36
ASHLEY RD	1,008	RANCH	1.88	2022-11-09	$115,000	$114.09
AVERAGE	**1,135**		**1.24**		**$137,965**	**$121.54**
MEDIAN	**1,020**		**0.94**		**$139,250**	**$136.52**
VALUE CHANGE FROM BEFORE SALES				**AVERAGE**		**14.59%**
				MEDIAN		**27.55%**

Current Production Practices for Cover Crops in Southeastern United States







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Abstract

As environmental sustainability awareness grows, the role of cover crops in preserving and enhancing cropland has become increasingly valued. This study surveys 46 farmers from January 28, 2021, to March 31, 2021, in Georgia, Alabama, and Florida to explore current practices in integrating cover crops into row crop production. Findings show cereal rye is the preferred cover crop, with no-till drill and broadcast spreading being the most common planting methods and herbicides the main termination method.

INTRODUCTION

With environmental sustainability issues becoming more widely recognized, the value of cover crops in the preservation and improvement of cropland has increased (Chatterjee, 2013; Kaspar and Singer, 2011; Wallander et al., 2021; Scavo et al., 2022). This resurgence is partly driven by increasing societal awareness of environmental issues but also the recognized challenge of soil degradation for the sustainable future of agriculture (Zulauf and Brown, 2019; Sawadgo and Plastina, 2022).

In the 2010-2011 season, cover crops were adopted by approximately 4% of farmers on some portion of their cropland, while less than 0.3% of farms used cover crops on all of their acreage (Wade, Claassen, and Wallander; 2015). By 2017, the United States Department of Agriculture Census of Agriculture reported that 12% of harvested row crop acreage in the U.S. included a cover crop in the rotation (U.S. Department of Agriculture, 2017). During this time, the adoption of cover crops in the Southeast was on the upswing, with the net increase in cover crop acres between 2012 and 2017 in the Southern Seaboard region reaching 460,447 acres (Sawadgo and Plastina, 2022). With a long production season due to warm weather, cover crops can be more extensively and successfully used in the Southeast than in other regions of the U.S. (Sarrantonio and Gallandt, 2003).

Cover crops have been recognized as a crucial component in diversified crop rotations (Snapp et al., 2005), providing both agronomic and economic benefits (Bayer et al., 2000). It has been found that implementing cover crops into existing crop rotations can improve or maintain soil quality, prevent erosion, increase biomass, and reduce the need for tillage (Kaspar, Radke, and Laflen, 2001). Cover crops can also improve groundwater quality from decreased nutrient leaching (Ruffo, Bullock, and Bollero, 2004), reduce irrigation water usage (Allen et al., 2005), suppress weeds (Fisk et al., 2001), increase beneficial insect conservation (Bowers et al., 2020), and increase carbon sequestration (Reicosky and Forcella, 1998).

However, only a few studies have focused on conservation practice use among Southeastern row crop producers (Varco, Spurlock, and Sanabria-Garro, 1999). Hancock et al. (2020) used focus group interviews to identify cost and revenue changes and the perceived advantages and challenges to the adoption of cover crops by Georgia's cotton and peanut producers. Researchers found that producers exhibited different preferences for cover crop species across irrigated and dryland cotton production in Texas (Fan et al., 2020a; Fan et al., 2020b). Plastina et al. (2018a; 2018b; 2018c; Plastina et al. 2023) conducted research in the Midwest to identify changes in costs and revenues associated with cover crops, but the production practices used with cover crops in the Southeast are largely unknown. Nassauer et al. (2011) used surveys to identify production practices when cover crops were used in a cash crop rotation, including cotton, peanuts, and corn in the Southeast. It is important to understand the production practices used when cover crops are implemented to determine what improvements can be made to increase efficiency and improve the efficacy of policies fostering adoption.

MATERIALS AND METHODS

In accordance with the methodology established by Plastina et al. (2018a; 2018b; 2018c), this study employed surveys to investigate the utilization of cover crops in row crop rotations across Georgia, Alabama, and Florida. To maintain consistency, participating farmers were instructed to consistently refer to the same farm throughout the survey, even if they owned or managed multiple farms. Detailed questions were asked regarding cover crop planting and termination methods, tillage practices, the subsequent cash crop, and the specific cover crop species or mix adopted.

Survey responses were collected through phone interviews, mailed questionnaires, and an online survey hosted on Qualtrics. Contact details for individual farmers were obtained by engaging county extension offices in Georgia and Florida, regional extension agents in Alabama, and research specialists from the University of Georgia Cooperative Extension Service, the Institute of Food and Agricultural Sciences (in collaboration with the University of Florida and Florida A&M University), and the Alabama Cooperative Extension System (in partnership with Auburn University and Alabama A&M University). Furthermore, various commodity groups and agricultural organizations, including the local Natural Resource Conservation Service centers, Georgia Cotton Commission, the Georgia Peanut Commission, the Georgia Corn Commission, the Alabama Peanut Producers Association, the Alabama Cotton Commission, and the Florida Peanut Producers Association, were contacted. County Farm Bureau offices in Georgia, state board members of the Florida Farm Bureau Federation, and leaders of the Alabama Farmers Federation were also contacted. These entities were requested to disseminate the online survey to relevant farmers.

A snowball sampling technique was employed to increase participant recruitment, with farmers asked to identify and recommend other potential participants. The data collection period spanned from January 28, 2021, to March 31, 2021, strategically chosen to avoid the cotton, peanut, and corn harvest and planting seasons. COVID-19-related travel restrictions during the survey period posed challenges in conducting in-person meetings, so to address this constraint, we offered farmers multiple avenues to complete the survey, including mailed paper surveys, access to the online survey, and phone interviews. A mixed-mode questionnaire and survey implementation method were adopted, adhering to the timeline proposed by Dillman et al. (2014) to optimize response rates, as illustrated in Figure 1.

RESULTS AND DISCUSSION

Farm Demographics

A total of 46 responses were obtained, and of the 44 farmers who specified the location of their farm, 31 (70%) were located across 22 counties in Georgia, primarily concentrated in the Southern region of the state. Florida producers provided nine (21%) responses, dispersed across seven counties in the Northern part of the state. Furthermore, four (9%) responses were received from farmers in Alabama, spanning four counties throughout the state. The majority of respondents had engaged in cover crop planting on their farms in recent years, with only two out of the 46 farmers indicating that they had never planted a cover crop.

Figure 2 presents an overview of the duration of cover crop adoption among producers. The predominant response indicates that a substantial number of farmers have been cultivating cover crops for 0-5 years, with fewer participants reporting cover crop engagement exceeding 20 years. Among the 43 responses answering for the question of the duration of cover crop adoption, the average duration of cover crop cultivation by producers was 11.47 years.

Figure 3 outlines the distribution of farm sizes among the survey respondents. The most prevalent farm size range was 202.3 to 404.3 hectares (500 to 999 acres), encompassing 24% of the 46 surveyed farms. Farm sizes exceeding 809.4 hectares (2,000 acres) and those falling within the range of 404.7 to 809.0 hectares (1,000 to 1,999 acres) were the next most frequent categories, representing 22% and 20% of the respondents, respectively. The predominant farm sizes among cover crop-utilizing producers in the surveyed region concentrated in the category above 202.3 hectares (500 acres) with medium- to large-scale agricultural operations.

In Figure 4, it is evident that cereal rye stands out as the predominant choice for cover crop monoculture among producers. Among the respondents, 49% (21) reported utilizing a cover crop monoculture, while the remaining 51% (22) opted for a mixed-species approach. This nearly equal split highlights the varied preferences for monoculture versus mixed-species cover crops among producers in the surveyed region.

Table 1 further details the specific mixes employed by the 21 farmers who adopted a mixed-species. Notably, nine of these mixes incorporated annual ryegrass, while 12 involved cereal rye. Additionally, various clover species and oats were common components of these mixes, with 10 responses including at least one variety of clover and 13 responses using at least one variety of oats. This diversity underscores the range of cover crop species employed by producers in the surveyed region. These species not only contribute to soil health and fertility but also align with the nutritional needs of livestock when cover crops are utilized for grazing. Farmers leveraging cover crops for grazing purposes may find these nutrient-dense options beneficial, potentially offsetting winter feed costs through grazing or harvesting for forage (Plastina et al., 2023).

Cover Crop Planting Practices

Figure 5 illustrates the distribution of area planted to cover crops in the most recent year across surveyed farms. The predominant range was 40.5-201.9 hectares (100-499 acres), suggesting that cover crops are typically not planted on the entirety of a farm's acreage, with the prevailing farm size falling within 202.3-404.3 hectares (500-999 acres) for the most common range. The data implies that farmers are selectively incorporating cover crops on specific portions of their land, rather than implementing them uniformly across the entire farm. Figure 6 illustrates the distribution of cover crop seed expenditures, where the average seed cost for monoculture was $58.14 per hectare ($23.53 per acre), and the average seed cost for cover crop mix was approximately $63.95 per hectare ($25.88 per acre).

In terms of cover crop management, the irrigation and fertilization practices employed by farmers were explored. From the 43 responses obtained from answering the question for irrigation and fertilization practices, a significant majority of farmers chose not to irrigate their cover crops. Only 19% of respondents irrigated their cover crop, including those who irrigate only a portion of their cover crop. Out of the respondents who irrigate, one farmer reported irrigating 100% of their cover crop, and an average irrigation amount of approximately 5.08 cm (two acre-inches) was applied by a subset of eight farmers. For fertilization practices, 58% of the 43 respondents applied fertilizer to at least some of their cover crop acreage. Among those who fertilize their cover crop, 17 farmers reported fertilizing 100% of their cover crop acres. Figure 7 discusses the types of fertilizers used, with nitrogen emerging as the most commonly applied fertilizer to cover crops. The fertilizer mentioned in the "Other" category is sulfur.

In our investigation of cover crop-related expenses, we delved into the hiring of custom work for cover crop planting among farmers. Out of 43 respondents answering the question of custom work, five respondents (12%) acknowledged hiring custom planting services for at least a portion of their cover crop area. Among these respondents, three farmers used custom broadcast seeding, while the remaining two chose custom drilling as their planting method. The associated costs averaged $51.08 per hectare ($20.67 per acre) for custom broadcast seeding and $64.25 per hectare ($26.00 per acre) for custom drilling.

For those who did not opt for custom planting services, we explored the types of planting machinery they employed. Figure 8 illustrates that among the 39 responses answered the question for custom planting service, the no-till drill and broadcast seeder are the two most commonly used types of planting machinery for cover crops. In terms of power of the tractor used, the majority of farmers used a four-wheel-drive tractor, with a horsepower range of 200-399. Additionally, 17 farmers reported utilizing a two-wheel-drive tractor, with horsepower ranging from 30-179.

Cover Crop Termination Methods

Figure 9 provides an overview of methods used during cover crop termination among sampled farmers. A total 39 responses answered the question of cover crop termination method, 32 farmers opted for herbicide application to terminate their cover crop, and 12 reported supplementing herbicide with another method, including roll/crimp, tillage, and mowing, while 17 relied solely on herbicide; three farmers didn't disclose the method they used in addition to herbicide. Seven farmers adhered to a singular cover crop termination method other than herbicide, including tillage, mowing, and roll/crimp.

Among the 32 farmers that used herbicide to terminate their cover crop, 30 farmers disclosed the associated herbicide costs, reporting an average expenditure of $29.75 per hectare ($12.04 per acre). Notably, none of the surveyed producers hired custom work for cover crop termination via herbicide. The breakdown of equipment used for herbicide application during cover crop termination includes 17 farmers employing a self-propelled sprayer, while nine farmers utilized a two-wheel-drive boom-type sprayer.

A significant portion of surveyed farmers expressed that the termination of their cover crop imposed minimal additional labor or costs. Only four farmers reported the need for extra, unpaid labor hours for herbicide-based termination, averaging 13.74 hours per hectare (5.56 hours per acre). Additionally, only five farmers indicated incurring supplementary expenses associated with herbicide termination, with an average cost of $98.84 per hectare ($40.00 per acre). These findings align with expectations, considering that many farmers already integrate herbicide application into their routine spring field preparation practices. For these practitioners, applying herbicide to the cover crop likely entails comparable costs, both in terms of expenditure and managerial hours, to applying herbicide in fields without cover crops. Notably, farmers not habitually using herbicide in their spring field preparation sometimes experience less favorable returns on investment, as they face additional costs for herbicide purchase in cover crop termination.

Among the participants utilizing tillage in the termination process of their cover crop, six out of seven respondents provided detailed insights into their tillage practices. Notably, only one farmer opted for custom tillage work, incurring a cost of $61.78 per hectare ($25 per acre). For those who undertook the termination themselves, three employed a two-wheel-drive tractor with horsepower ranging from 30-179, while two used a four-wheel-drive tractor with horsepower ranging from 200-339. Each farmer utilized different tillage implements, including a spring tooth harrow, row crop cultivator, disk plow, vertical tillage tool, and a roller harrow. Only one f armer reported increased expenses and unpaid labor hours for tillage-based termination. This respondent detailed 9.88 unpaid labor hours per hectare (four unpaid labor hours per acre) and $197.68 per hectare ($80 per acre) in extra expenses. Moreover, two out of five farmers exclusively tilled fields to terminate cover crops, and an equal number reported cover cropping on all their row crop acreage. The findings suggest that farmers accustomed to tilling their fields, regardless of the presence of a cover crop, generally do not incur additional expenses for cover crop termination through tillage.

Three out of six farmers who opted for mowing as their chosen termination method for cover crops provided detailed insights into their termination practices, with none of them using custom mowing services. Notably, one farmer reported employing a two-wheel-drive tractor with a horsepower range of 120-149, and each farmer utilized different mowing implements, including a rotary mower, flail mower, and a mower conditioner. Among these farmers, two reported incurring additional expenses and unpaid labor hours for cover crop termination by mowing. The average additional unpaid labor hours required were 12.68 hours per hectare[1] (5.13 hours per acre), and one farmer reported spending an extra $37.07 per hectare ($15 per acre) for mowing as a termination method. Each of the three farmers exclusively mowed acreage under a cover crop, with only one planting cover crops across all of their acreage. Given that mowing is not a conventional method for spring field preparation, the findings suggest that additional expenses may be incurred, particularly when mowing is used exclusively on acreage with a cover crop present.

A subset of five farmers provided detailed insights into their utilization of rolling/crimping as a termination method for cover crops. Three of them adopted a single-pass approach, terminating their cover crop by combining herbicide application with rolling/crimping in the same pass. The remaining two farmers opted for a two-pass strategy, applying herbicide in one pass and subsequently employing rolling/crimping. Farmers personally executed the rolling/crimping process, with none of them seeking custom rolling/crimping services for cover crop termination. The equipment used varied, as two farmers utilized a two-wheel-drive tractor with a horsepower range of 120-179, while the other three farmers employed a four-wheel-drive tractor with horsepower ranging from 200-339. The choice of rolling/crimping implements also differed, with two farmers using a smooth drum roller, and the remaining three employing a dedicated roller/crimper. Only one farmer reported incurring additional expenses or unpaid labor hours from terminating the cover crop by rolling/crimping. Four out of the five farmers emphasized that they exclusively employed rolling/crimping on areas with cover crops, and three of these farmers covered all their acreage with a cover crop.

Cash Crop Tillage Practices Following Cover Crop

To ascertain the impact of cover crops on tillage practices for succeeding cash crops, our survey asked the tillage methods adopted by farmers following cover crop cycles. The responses revealed a range of practices. Six farmers indicated their use of reduced tillage practices following both cover crops and fallow. Additionally, one farmer employed rotational no-till practices consistently, whether a cover crop was present or not.

The next inquiry focused on the number of tillage passes employed to prepare fields for planting the subsequent cash crop. Among the eight farmers who provided insights into tillage passes, Figure 10 showcases that 50% of them opted for a single tillage pass to ready the field for the next cash crop. It is worth noting that conventional tillage systems in the Southeastern U.S. typically involve an average of two to three tillage passes. The adoption of cover crops presents the potential to reduce the number of tillage passes to just one, a reduction that not only signifies a significant decrease in soil disturbance but also highlights the potential for improved soil health and conservation practices associated with cover crop adoption. By minimizing tillage intensity, farmers can mitigate soil erosion, enhance water infiltration, and promote the retention of soil organic matter, ultimately leading to more sustainable and resilient agricultural systems.

To gain a deeper understanding, respondents were asked to specify the type of tillage implement used for each pass. For the first pass, two farmers reported using a strip-till rig, while the remaining three utilized a strip-till rig with an integrated roller for field preparation. Among the three farmers resorting to a second tillage pass, each employed a distinct implement, ranging from a strip-till rig to a strip-till rig with a roller to a chisel plow. The farmer conducting a third tillage pass opted for a strip-till rig equipped with a roller.

SUMMARY AND CONCLUSIONS

Our research sheds light on the multiplicity of agronomic and management practices that farmers implement when using cover crops, particularly in the Southeastern U.S. The majority of respondents, encompassing a diverse range of farm sizes, reported incorporating cover crops for a duration of 0-5 years. The predominant use of cereal rye, with its notable environmental benefits, emerges as a preferred choice among farmers.

Cover crop termination methods primarily involve herbicide with other termination methods like rolling/crimping, mowing, or tillage. The majority of farmers do not incur additional labor or costs during cover crop termination, highlighting the relative synergies between termination practices and existing field preparation routines. Insights into post-cover crop tillage practices indicate a significant joint adoption of cover crops with reduced tillage, showcasing the potential of cover crops to influence system-wide farm management decisions. The majority of respondents among farmers who adopted cover crops opted for one or two tillage passes, often employing strip-till rigs or other implements aligned with conservation tillage principles. Compared to conventional tillage systems in the Southeastern U.S., which typically involve an average of two to three tillage passes, the adoption of cover crops has the potential to reduce tillage passes.

The results of this study contribute valuable insights into the myriad practices that farmers in the Southeastern U.S. need to consider when implementing cover crops. Future research on the economic costs and benefits of cover crop adoption is needed to help producers evaluate their options in incorporating cover crops into their farm management practices. In turn, these results should raise awareness among policymakers and conservation groups about the private costs faced by farmers implementing cover crops and the need for continued technical and financial support. It would also assist policymakers in designing incentive programs to encourage adoption. Policies encouraging cover crop adoption could include financial incentives such as cost-sharing programs, subsidies, or tax credits to offset initial costs. Education and outreach initiatives, including technical assistance and demonstration projects, could help producers understand the long-term benefits. Additionally, integrating cover crop requirements or incentives into conservation programs, crop insurance discounts, or carbon credit markets could further promote adoption.

FOOTNOTES

1 Two respondents provided responses to this question, with one respondent indicating an increase of 24.71 additional unpaid labor hours per hectare (10 additional unpaid labor hours per acre) and the other 0.62 additional unpaid labor hours per hectare (0.25 additional hours per acre). The respondent who reported 10 additional unpaid labor hours employs a mixed cover crop system consisting of various varieties, including annual ryegrass, Austrian winter peas, cereal rye, crimson clover, hairy vetch, mustards, oats, radish, rapeseed, turnips, and triticale.

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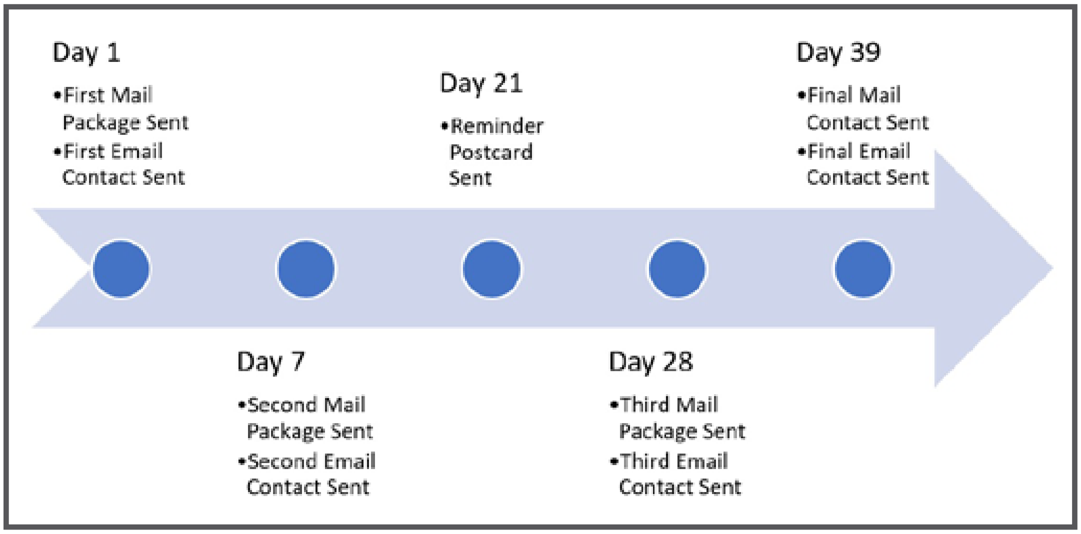


Figure 1. Survey timeline for paper and online surveys in cover crop research

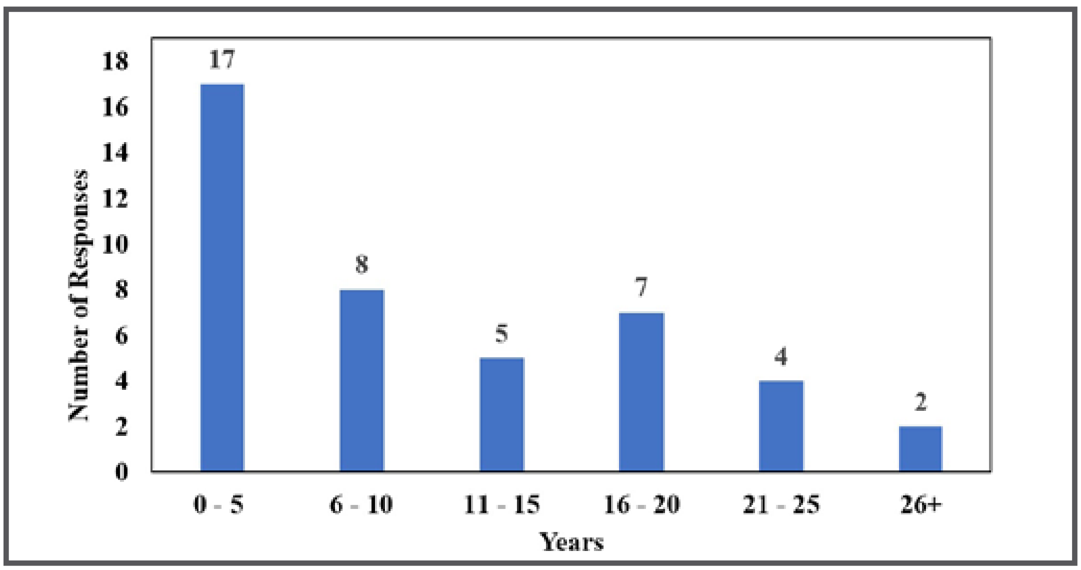


Figure 2. Duration of cover crop adoption across farm

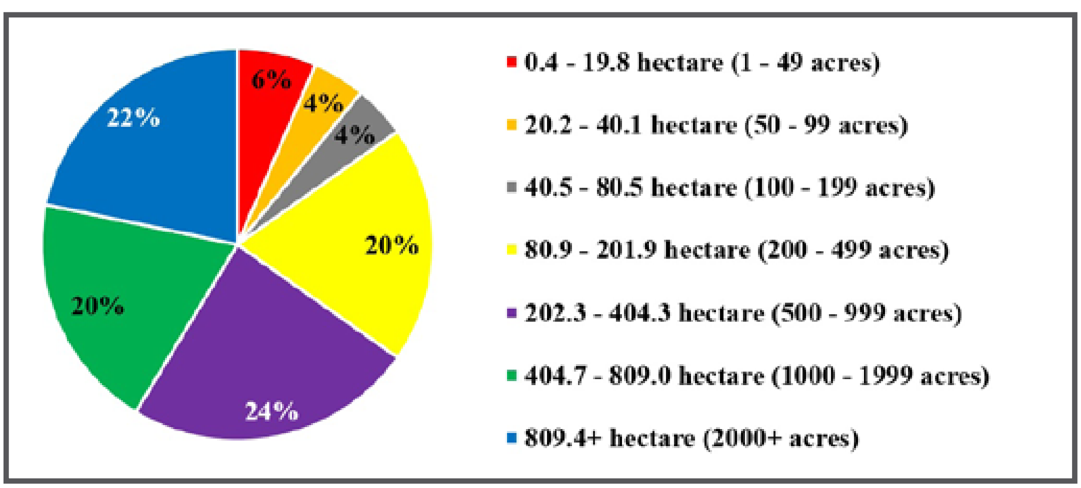


Figure 3. Percentage distribution of responses across farm size ranges

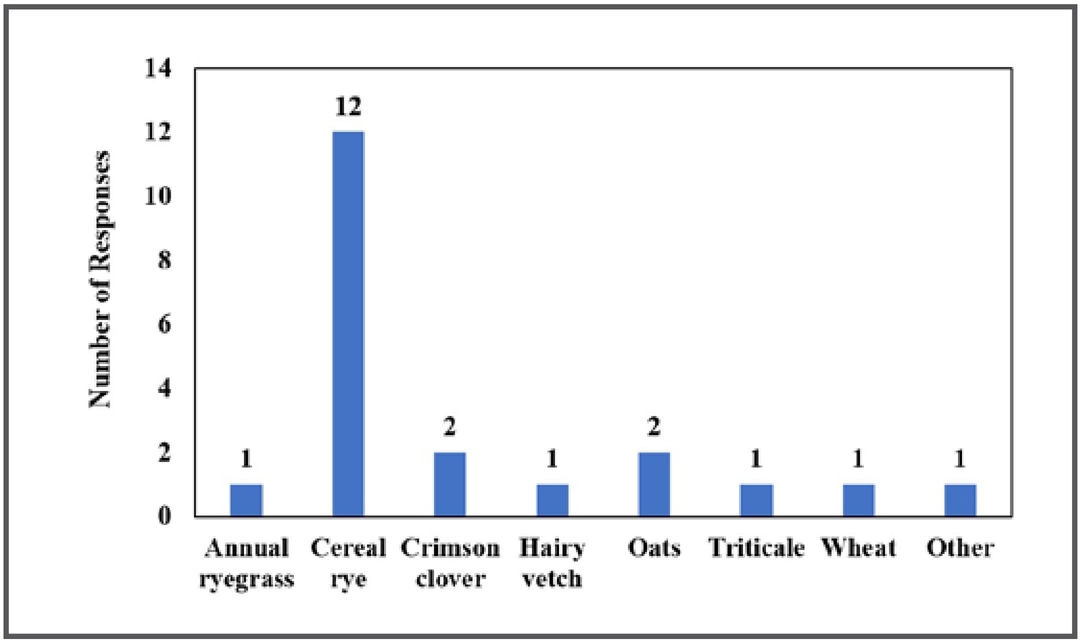


Figure 4. Species planted as cover crop monoculture

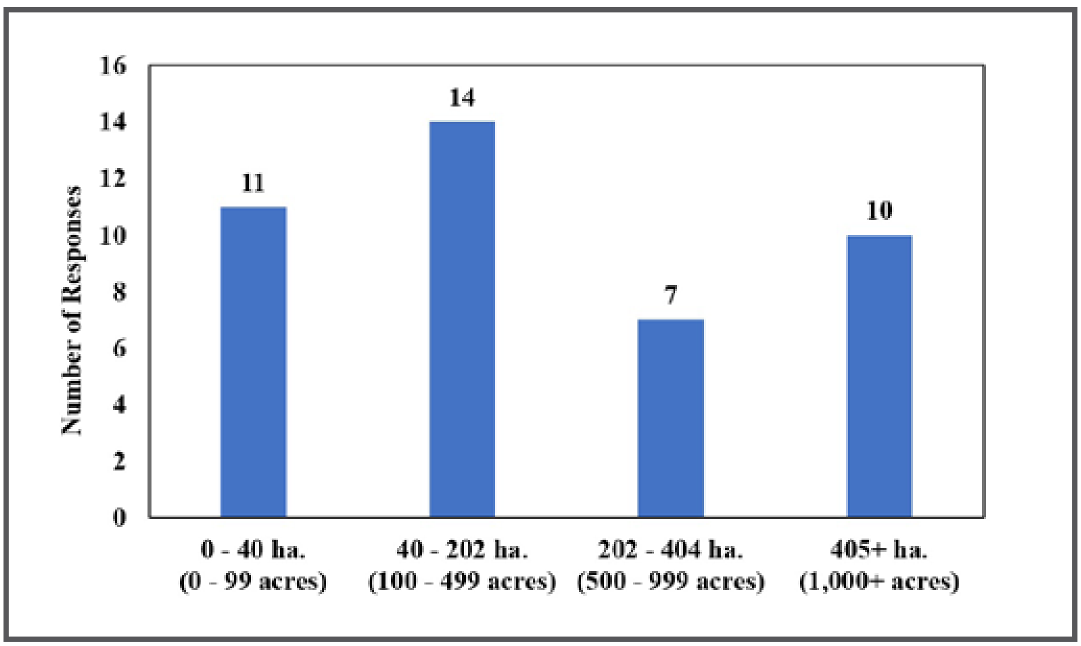


Figure 5. Acres dedicated to cover crop in the most recent year on the farm

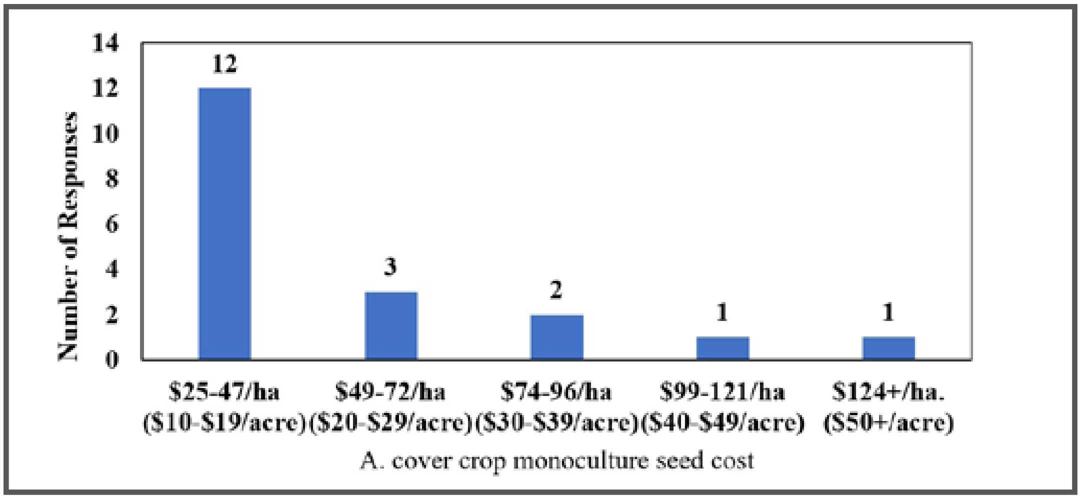


Figure 6. Seed cost per acre for cover crop

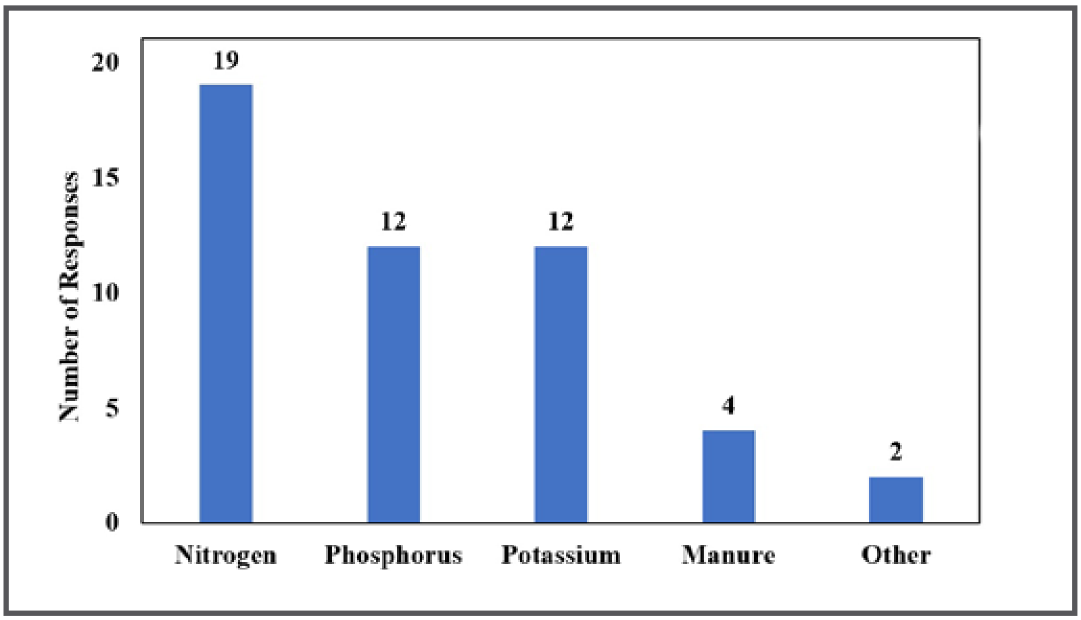


Figure 7. Type of fertilizer applied to cover crop

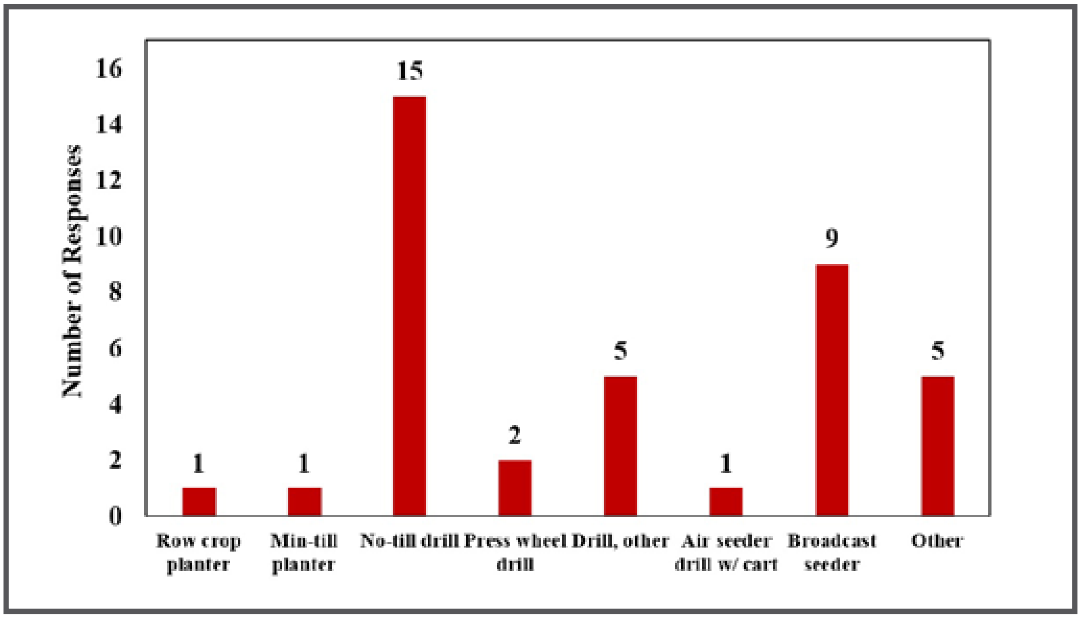


Figure 8. Type of planting machinery used to plant cover crop

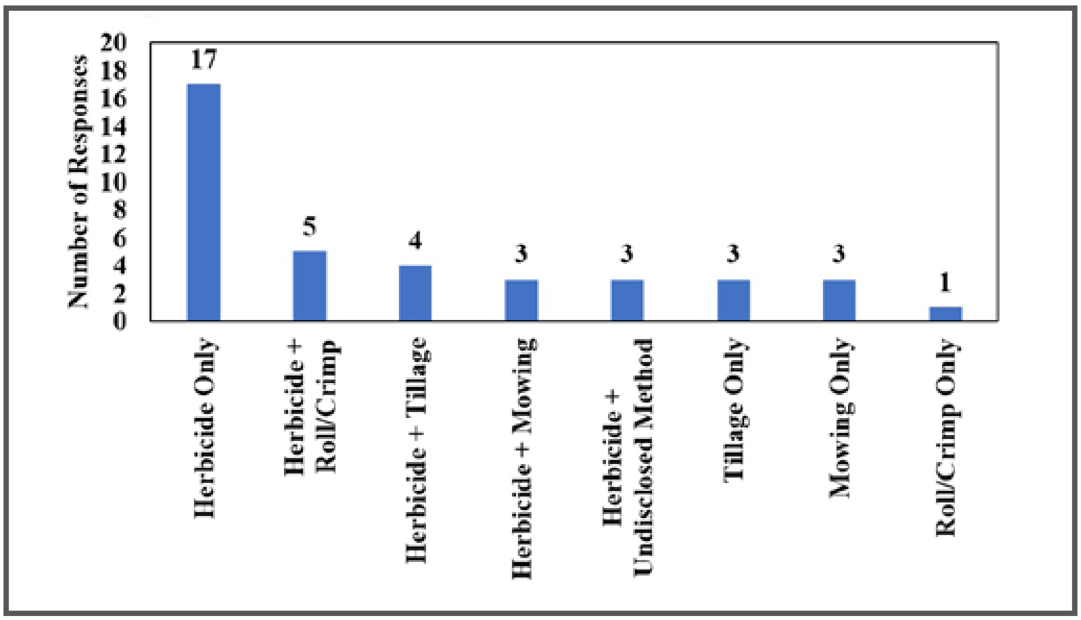


Figure 9. Diverse termination methods employed by survey respondents for cover crop termination

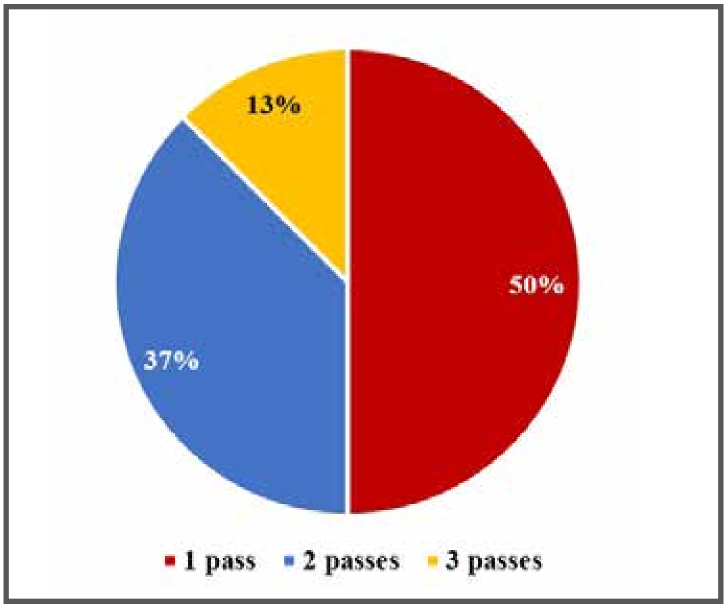
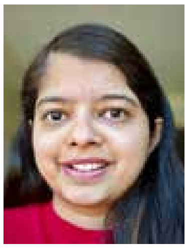
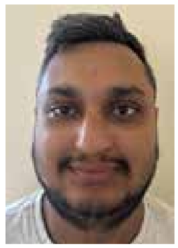


Figure 10. Number of tillage passes employed in field preparation for cash crop following cover crop

Table 1. Diversity in Cover Crop Mixes Utilized by Southeastern Row Crop Producers

Mix Number	Cover Crop Mix	Number of Responses
1.	barley + sugar beets	1
2.	crimson clover + oats	1
3.	annual ryegrass + cereal rye + oats + wheat	1
4.	Austrian winter peas + cereal rye + crimson clover + hairy vetch + mustards + oats + radish + rapeseed + turnips + triticale + wheat + balansa clover	1
5.	annual ryegrass + Austrian winter peas	1
6.	annual ryegrass + Austrian winter peas + cereal rye + crimson clover + hairy vetch + mustards + oats + radish + rapeseed + turnips + triticale	1
7.	annual ryegrass + white clover	1
8.	annual ryegrass + cereal rye + oats + triticale	1
9.	cereal rye + hairy vetch + mustards + oats + radish + turnips + wheat + black oats	1
10.	cereal rye + crimson clover + mustards + radish	1
11.	Cosaque black oats + balancia fixation clover	1
12.	cereal rye + millet + crabgrass	1
13.	annual ryegrass + Austrian winter peas + cereal rye + crimson clover + hairy vetch + oats + turnips	1
14.	annual ryegrass + crimson clover + wheat	1
15.	radish + wheat	1
16.	cereal rye + wheat	1
17.	annual ryegrass + oats + wheat	1
18.	cereal rye + oats	1
19.	Austrian winter peas + cereal rye + crimson clover + hairy vetch + radish	1
20.	annual ryegrass + cereal rye + crimson clover + oat + radish + wheat	1
21.	oats + wheat	2

Recent H-2A Wage Hikes' Divergent Effects on Workers' Welfare and Farm Business Viability

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Abstract

Starting in 2023, the H-2A program's adverse effect wage rate (AEWR) suddenly increased significantly in several states. This article demonstrates the policy's two conflicting sides. Disparities in regional AEWR growth and living wage gaps validate the policy's subscription to the social equalizing principle that protects workers' rights to fair compensation. Our analysis, however, also presents serious business repercussions confirming many farmers' claims of significantly deteriorating incomes and profit margins. This study reminds policymakers to carefully balance policy consequences affecting different constituent groups, with consideration given on timing, targeting, and remedial follow-up measures to mitigate adverse effects on affected sectors.

BACKGROUND

The U.S. farm sector generally relies on foreign farm workers for its seasonal unskilled labor needs (Escalante, Cowart, and Shonkwiler, 2023; Escalante, Perkins, and Santos, 2011). Domestic residents are usually hesitant to take on farm jobs as they normally involve physically demanding manual tasks and could expose them to serious health risks (Luo and Escalante, 2017). Potential farm workers are especially discouraged by the relatively inferior compensation and remuneration rates offered for unskilled labor that are not commensurate with the physical demands, health hazards, and work conditions they must endure (Luo and Escalante, 2017; Escalante, Wu, and Li, 2016).

After stricter immigration control policies evicted many undocumented farm workers, the farm sector relied on the H-2A Agricultural Guest Worker Program for its foreign labor needs. The program allows agribusinesses to temporarily hire non-immigrant foreign workers to perform full-time, short-term (seasonal) farm work when willing domestic workers are not available (GAO, 1997). Cognizant of the farm sector's domestic labor hiring and compensation negotiation challenges, the H-2A program was deliberately designed under federal regulations to protect the welfare and interests of foreign workers while ensuring that such hiring decisions do not displace potentially qualified domestic workers. Specifically, the H-2A program sets minimum standards for provision of housing, transportation, meals, workers' compensation, and other benefits (Mayer, 2008). Moreover, the program subscribes to a minimum hiring wage provision by having the Adverse Effect Wage Rate (AEWR) determined under a state-level, federally designed, mechanism. Technically, the AEWR mechanism serves a twofold objective:

to uphold foreign workers' welfare and to avert any possibility that H-2A wages could "adversely" affect U.S. farm labor market conditions if such wages are set too low, thereby dwindling the wage rate of domestic workers (UFW n. DOL, 2020; Rutledge et al., 2023).

Despite its economic and market foundations, the AEWR-setting mechanism has often drawn criticisms. Some contend that state-level AEWRs can be quite high, and when such rates are factored into the program's remuneration package, which already includes heftier fringe benefits, the H-2A program becomes too expensive, to the point where some businesses find it to unaffordable, and hence, it becomes a less viable labor sourcing option for farms (Critterden, 2020).

Nonetheless, H-2A program patronage has grown in recent years as farmers' hiring options have run out, and they've had to inevitably resort to "more expensive" foreign labor for the sake of sustaining farm business operations after many unsuccessful attempts to lure a reluctant domestic labor market (Escalante, Luo, and Taylor, 2020). Between 2013 and 2019, the farm sector's reliance on H-2A labor has grown, with the proportion of H-2A visa approvals to aggregate employment in the farming, fisheries, and forestry sectors increasing from 7.69% to 17.71% (Escalante, Luo, and Taylor, 2020).

In 2023, the Department of Labor (DOL) released state AEWRs that reflect radically, unusually high annual growth rates that exceed historical trends. The AEWR growth momentum was sustained the following year when levels in most states continued their upward trend.

As any policy always has multifaceted implications, this article will shed light on the important repercussions of these sudden, sharp increments in AEWRs. In this study, we present two contrasting perspectives coming from the farm workers and the agribusiness owners/operators. The following sections will discuss separately the social and economic effects of such wage policy developments on workers' welfare and farm business viability, respectively.

THE FARM LABOR PERSPECTIVE

Figure 1 presents historical plots of national average AEWRs and minimum wages from 1991 to 2024. While the AEWR is consistently higher than the minimum wage in all years, the gap between these two wage indexes started to widen in the 2000s, especially after 2010. Since 2022, the national average AEWR has already been more than twice as much as the minimum wage.

In 2023 and 2024, state-level AEWRs posted annual increments averaging 7.49% and 5.26%, respectively, which were considered to be unprecedented and exorbitant as they surpass the wage rate's historical growth trends. The national average 2022 rate of $15.03 rose to $16.13 in 2023, with the upward trend sustained through 2024 when the average rate was set at $16.98.[1]

In this article, we present explanations for the sudden rise in state-level AEWRs in 2023 and 2024 through scrutiny of regional and intertemporal trends. Moreover, the minimum wage-AEWR gap analysis is extended to include more intuitive, realistic measures of worker welfare.

Regional Levels and Growth Disparities

In theory, the determination of AEWRs at the state level is inherently rooted in geographic differences in living conditions. Regional aggregation[2] of state AEWRs reveals that farm wages in the South are among the lowest in the nation, while Midwest farms pay the highest average regional wages among the production regions (Table 1). In 2000, for instance, the average AEWR in the South was $6.72 per hour, while workers in the Midwest were paid $7.68 per hour on average, separated by almost a dollar ($0.96). In 2019, the difference between the lowest (South) and highest (Midwest) regional AEWRs became wider at $2.05 ($11.33 versus $13.38, respectively).

Interestingly, state-level minimum wages in the South are not usually the lowest across the different regions. The Plains have consistently registered the lowest average regional minimum wage since 2000 (Table 1). In 2024, the region's average minimum wage was $8.70 per hour, while Atlantic states paid a minimum wage of $12.86 per hour.

The historical regional AEWR growth trends could shed light on the abrupt rise in 2023 and 2024 levels. In 2024, the South's AEWR ($14.74 per hour) grew by 8.13% over its 2022 level, which was the highest regional growth rate. The South has consistently registered the lowest annual AEWR growth rate among all regions since 2000, but prior to 2022, the South's annual AEWR increases were quite modest and sluggish compared to the other regions. During the period 2019-2022, the South's AEWR only grew by 3.64%, which was its fastest growth prior to the 2023-2024 surge. Notably, the South also began its aggressive minimum wage hikes during this period when it registered the second highest regional growth rate at 5.13% percent (outpaced by the Atlantic region's 5.71%); the growth momentum would be sustained in 2022-2024 when minimum wages in the region grew on average by 6.66% (second to the West region's 7.70%).

The Midwest registered the second highest annual AEWR growth from 2022 to 2024 at 7.22%. However, like the other regions (Atlantic, Plains, and West), the upward adjustment began much earlier, as the Midwest's AEWRs have been increasing from 5% to 6% annually since 2019. Thus, from a regional perspective, the sharp rises in AEWRs in 2023 and 2024 could have been a more imperative policy decision. The rationale comes from the need to rectify the region's past sluggish or delayed AEWR adjustments and minimize regional wage discrepancies by recalibrating the region's AEWR to come close to (or be at par with) the higher wages in other production regions.

AEWR as a Social Equalizing Tool

The AEWR principle clearly manifests itself as a social equalizing tool that upholds workers' rights to receive adequate, fair, and just compensation. We validate this contention by relating the recent significant spikes in AEWRs to the concept of livable wages. Specifically, the newly upgraded AEWRs are compared to prevailing livable wage rates derived from the Massachusetts Institute of Technology (MIT)'s Living Wage Calculator (MIT, 2024). The MIT dataset consists of annual average state livable (living) wages that individuals must earn to afford basic needs (food, housing, transportation, taxes, and inflation) on their own, devoid of any further external assistance.

In this analysis, we calculate the gap between AEWR and livable wage rate per hour (LWH) by evaluating the ratio $\left(\frac{AEWR}{LWH}\right)$. A gap exists for ratio levels less than 1. Our calculations are made under the following conditions:

- Among the different MIT household scenarios, our analysis utilizes MIT's LWH estimates for a single adult with no children, which conforms to a typical H-2A worker's living arrangement (with no accompanying dependents residing with him/her).
- State-level AEWRs are adjusted by an additional wage premium suggested by Calvin, Martin, Simnitt (2022), factoring in H2A's additional fringe benefits (including housing and transportation), which could add $2.55 per hour in hourly wages and factored together with offsetting employers' benefits of non-payment of social security and unemployment taxes.

Based on the bar plots in Figure 2, the AEWR:LWH gaps for the Midwest and Plains regions were eliminated by 2024 as their ratios reached the 1.00 demarcation line. The large AEWR increments in the last two years, however, only reduced the gaps for the other regions but not enough for the gaps to be eliminated completely. After the 2024 AEWR increase, the average AEWR:LWH ratio for the Atlantic region improved to 0.86, while the average ratios for the West and South regions reached 0.84.

Table 2 presents crucial information applicable to the domestic farm workers' living and welfare conditions. In this analysis, it is important to clarify that DOL's primary bases for setting state-level AEWRs are the farm workers' responses in the previous year's Farm Labor Survey conducted by the U.S. Department of Agriculture (USDA) among crop and livestock workers. Notably, the responses to these annual surveys mostly come from domestic farm workers who do not enjoy the same fringe benefits (housing, transportation, meals, insurance, and others) that H-2A workers are provided with. Hence, in determining the AEWR:LWH gap applicable to domestic unskilled farm workers, unadjusted AEWR data is used instead, since local workers do not generally receive such H-2A fringe benefits. The unadjusted AEWR:LWH ratios in Table 2 sheds light on the more unfortunate living situations of domestic farm workers. Based on the results, all regional gaps remain unresolved even after the stark AEWR increases in the last two years. By 2024, the gaps in the Midwest and Plains regions were only reduced to 0.13, while the other regions' gaps ranged from 0.25 to 0.28. These results only confirm the domestic farm workers' inferior compensation situation relative to their foreign counterparts.

THE BUSINESS PERSPECTIVE

While the steady rise in state AEWRs in recent years upholds the social equity and welfare principle for H-2A workers, the business side of the industry suffers. The sudden radical increases in state AEWRs in 2023 and 2024 have drawn criticisms and protests at the local, regional, and national levels from farmers and their supporters in the industry and the government. Since late 2023, when expectations were high that the DOL was poised to sustain the 2023 AEWR increasing trend into 2024, farmers in Michigan, North Dakota, and Georgia (among others) called for a freeze in AEWR levels, claiming that higher labor costs would threaten the survival and viability of farms that were already struggling with much elevated input costs brought about by, among other factors, pandemic-induced inflationary pressure (Georgia Farm Bureau, 2024; Cramer, 2024; Sloup, 2024; Vegetable Grower News, 2023a). The Georgia Fruit and Vegetable Association (GFVA), in cooperation with the National Council of Agricultural Employers (NCAE), submitted its official petition to the DOL with the additional request to modify and repeal the agency's methodology for deriving each year's AEWR (Georgia Farm Bureau, 2024). The American Farm Bureau (AFB) released an official statement of opposition to DOL's AEWR setting decisions (The Fence Post, 2023). In Congress, farmers' pleas gained support as Senators Ossoff (D-GA) and Tillis (R-NC) sponsored a bill in 2023, the "Farm Operations Support Act," that demanded the rollback of 2023 AEWRs to their 2022 levels (Vegetable Grower News, 2023b). The following year, Congressman Moolenaar (R-MI) revived the previous year's bill by introducing HR 7046 ("Supporting Farm Operations Act"), calling for a two-year freeze on AEWR levels (Shike, 2024).

More Labor-Intensive Farm Businesses

Across the U.S. farm sector, AEWR-setting policy decisions can have immediate, direct effects on regions and industries that are more highly dependent on H-2A labor. The South has emerged as the top regional H-2A employer, with about 45% of all certified H-2A workers in 2019 to 2021 (Escalante and Acharya, 2023). The West is right behind, with a roughly 29% share of the nation's total H-2A employment during the same period.

In terms of industry affiliations, farms engaged in fruit, vegetable, and horticultural production employ about 80% of the country's H-2A workforce in recent years (Castillo et al., 2021; Escalante, 2023). These industries' usual labor input requirements are substantial at every stage of their production processes, starting from the pre-planting until the post-harvest phase. The peak of their labor needs occurs during the harvest season, as the current nature of their operations requires mostly manual labor (Huffman, 2005).

Table 3 summarizes gross cash farm receipts (GCFRs) and labor data for U.S. fruit and vegetable farms to provide an overview of the labor-intensive nature of these industries' operations. These two industries are projected to register a combined GCFR of about $50 billion in 2024. Estimated total labor costs in 2024 amount to $22.8 billion for U.S. fruit and vegetable farms, under the assumption that labor accounts for 45% and 40%, respectively, of GCFR. In 2024, more than 375,000 H-2A positions have been certified by the DOL, of which 44% are expected to be employed in fruit and vegetable farms.

Anecdotal Evidence

Lewis Taylor Farms, Inc., a large corporate farm in South Georgia that is engaged in vegetable and greenhouse production, echoes the worries, concerns, and predicaments of many H-2A labor-dependent farms in the country (Caraway, 2023). The farm was among the first to hire H-2A workers in Georgia in 1997 and currently depends on the program for 80% of its labor needs (Vegetable Grower News, 2023c). The farm's struggles to employ domestic residents, even during periods of economic downturn with serious unemployment conditions, led it to the H-2A hiring option that has since sustained its operations. Currently, the farm employs 455 H-2A workers during the growing season, 50 local year-round workers, and another 250 H-2A workers during the harvesting phase of the production season (Caraway, 2023).

Bill Brim, the company's CEO and co-owner, explains that the 2023 AEWR hike alone already cost the company an additional $2.5 million in wage costs. He clarifies that such cost increases will be a difficult operating challenge for the business as the previous year's profit margins were not "wide enough to support wages at that level" (Caraway, 2023).

Declining Farm Incomes and Margins

This article provides evidence that corroborates farmers' anecdotal claims. Our analysis utilizes farm financial performance data compiled by the Economic Research Service of the U.S. Department of Agriculture (USDA-ERS) to calculate annual Value of Farm Production (VFP) for all U.S. farms.

The income effect of the 2023 and 2024 AEWR increases is initially determined for a normal, average U.S. operating farm scenario in 2024 as depicted in the USDA-ERS's projected VFP statement. The income effect derivation process uses the following parameters:

- Total Factor Payments (TFPs), comprising 16.25% of VFP, are allocated among rent, interest, and labor.
- For an average U.S. farm, labor costs account for 44.10% of TFP. In order to account for the relatively more labor-intensive nature of other U.S. farms, the labor cost segment of TFP is augmented in 5% increments until the desired labor cost-TFP proportion of about 80% is achieved (realized

when TFP is inflated by about 40%). The 80% mark coincides with claims of some fruit and vegetable farms, such as Lewis Taylor Farms, Inc.

- TFP's proportion to VFP is further adjusted by two factors: the Labor Intensity Factor (LIF) adjustment in the bullet point above and the AEWR growth plus the attendant H-2A labor cost differential due to additional fringe benefits.
- An adjusted net income margin is then derived using the newly adjusted TFP and applied to the 2024 VFP to obtain the adjusted net farm income estimate and the resulting net income margin.

Table 4 summarizes the results of the income effect analysis. The top half panel reports the income effect under an average AEWR growth scenario (6.38% for two-year growth). Results indicate that for an average U.S farm, net farm income will decline by 6.42%, while the net income margin will fall by 1.33%. In the most labor-intensive case in these states (40% increase in labor's TFP share), the income and margin reductions are 12.25% and 2.54%, respectively.

The income effect is expectedly more substantial in states that recorded the highest growth in the last two years (Georgia, Alabama, and South Carolina with a 10.70% increase). Based on the results in the lower panel of Table 4, a regular, relatively less labor-intensive farm will experience a 10.77% and 2.23% decline in net income levels and margins. More labor-intensive farms' profitability will be more adversely affected as net incomes and margins will drop by as much as 21% and 4%, respectively.

Figure 3 recalls the regional AEWR growth rates for 2022 to 2024 (last row of Table 1) and presents the plots of the changes in net farm income levels and under different LIF scenarios. The South, which has been the consistent largest regional patron of H-2A workers in recent years, records the worst regional case income squeeze scenario. Fruit and vegetable farms in the region normally fall under the 25% to 40% labor increment in TFP share and, thus, would stand to experience income reductions ranging from 12.8% to 15.6%. In contrast, the fruit and vegetable farms in the West, which is another popular work destination for H-2A workers, would experience slightly less income strains as incomes could fall by only about 8.1% to 9.9%. The nature of these regions' handling and timing of AEWR increases explains the differing trends in income repercussions.

SUMMARY AND IMPLICATIONS

This article demonstrates an instance where policymakers grapple with a difficult predicament when laying out policies for their constituents. Policy formulation has always been an intricate and challenging process as policymakers, on one hand, are bound to always uphold the preservation of the general welfare, but on the other hand, confront the reality that segments of its constituents could have varied, at times conflicting, demands and needs.

In our analysis, recent spikes in AEWRs set in an abrupt, unprecedented manner have drawn mixed reactions from different sectors in the economy. On one end, workers' rights advocates and their supporters commend the move for its alignment with social equalization principles that promote the prioritization of workers' rights to fair, equitable work compensation. On another front, however, the businesses of these workers' employers must endure and cope with the deterioration of profits and margins that could threaten business viability. In essence, every policy decision must carefully ensure the balancing of all its possible repercussions by avoiding the alienation or sacrifice of specific segments in society while satisfying others' concerns and needs.

The AEWR case is an example of policymaking's difficult, challenging, balancing ordeal. In many policy discussions around this issue, some have recommended the alternative adoption of more gradual AEWR increases instead of the actual, sudden rate spikes in several states, even if these were designed to rectify historical oversights. Moderate annual rate increases could provide producers with some lead time to lay out coping business strategies over an interim period lasting until the target, equalizing AEWR levels are eventually and ultimately realized.

A crucial consideration in this balancing approach is the timing of policy enactment. The substantial minimization of wage-living gaps, if not its complete eradication, is a time-sensitive imperative that must not be delayed for a significantly long period of time. When policymakers address this imperative, they must also deliberately factor in the agribusiness sector's tolerance and financial endurance to determine a reasonable time frame to implement such policy. The combined goals of timing and balancing requires the determination of an implementation period that is mutually feasible and acceptable for both workers and farmers.

At times, however, potentially polarizing policies may be deemed inevitable and cannot be delayed. In these situations, there seem to be no compromising solutions to address serious issues that need to be urgently addressed. In these instances, the government must quickly and promptly introduce mitigating policies to effectively offset any impending negative situations caused by the original policy. In the AEWR issue, for example, several policy ideas benefiting affected farm businesses could be explored. The government could introduce supplementary policies aimed at tempering inflationary pressures, stabilizing prices of other farm inputs, and minimizing margin squeezes caused by more expensive H-2A labor. These would allow farm businesses, especially the more financially vulnerable ones, to realize offsetting input cost effects and at least maintain operating efficiencies and profit margins. Trade-related policies could be aimed at increasing domestic consumer dependence on locally produced commodities, improving local producers' competitive stance relative to their foreign counterparts, and strengthening global trading relationships. These trade reforms should resolve the local producers' market stature as they deal with competing foreign producers with access to significantly cheaper labor inputs.

All told, every policy must always have an unequivocal goal that should never be compromised. Without exception, any policy and its related extenuations must serve as fiscal tools of equity, inclusion, and fairness where everyone's welfare is subordinate to none.

FOOTNOTES

1 Between 2022 and 2024, the states with the 10 most significant AEWR growth trends posted average two-year growth rates ranging from 8.05% to 10.70%.

2 The regional groupings of U.S. states are as follows: ATLANTIC states include North Carolina, Virginia, West Virginia, Maryland, Connecticut, Massachusetts, New York, Vermont, New Hampshire, Maine, New Jersey, Rhode Island, and Delaware; MIDWEST states are Minnesota, Iowa, Wisconsin, Illinois, Missouri, Indiana, Ohio, Pennsylvania, and Michigan; PLAINS states are Nebraska, Kansas, Texas, North Dakota, South Dakota, and Oklahoma; WEST states include California, Washington, Oregon, Idaho, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Alaska, and Hawaii; and SOUTH states are Arkansas, Florida, Georgia, Louisiana, Mississippi, Alabama, Tennessee, South Carolina, and Kentucky.

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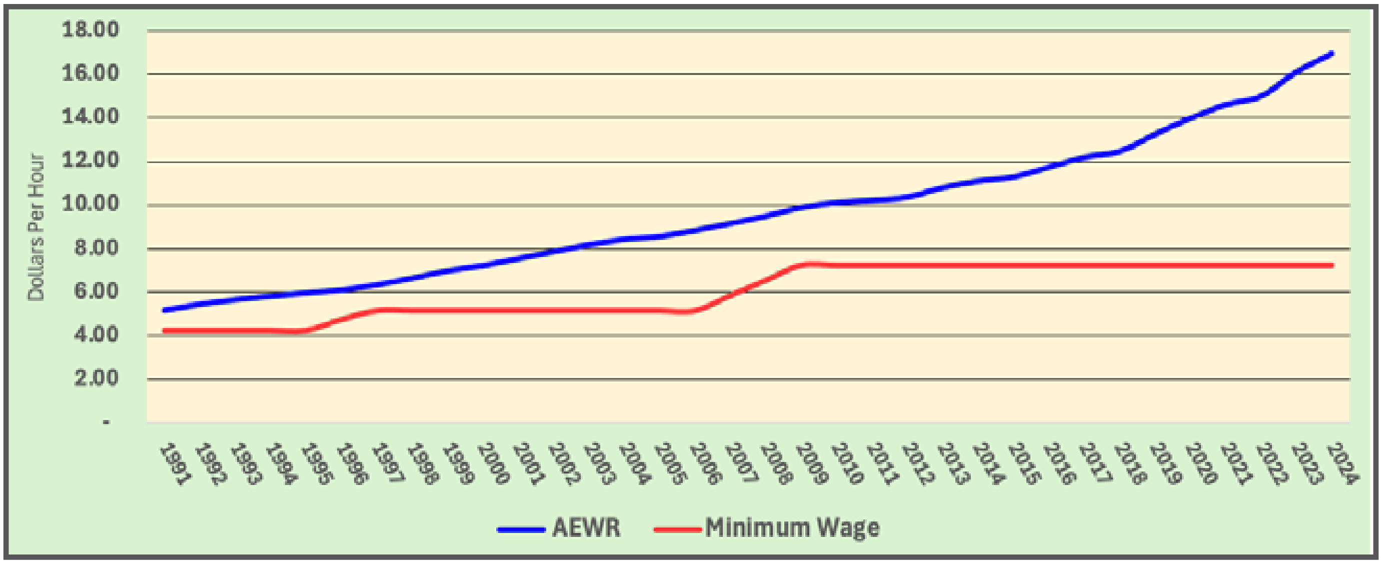

Figure 1. Historical levels of Adverse Effect Wage Rates (AEWRs) and minimum wages, national average, 1991–2024*

*Sources: Department of Labor, Foreign Labor Application Gateway (FLAG), and Wage and Hour Division (WHD)

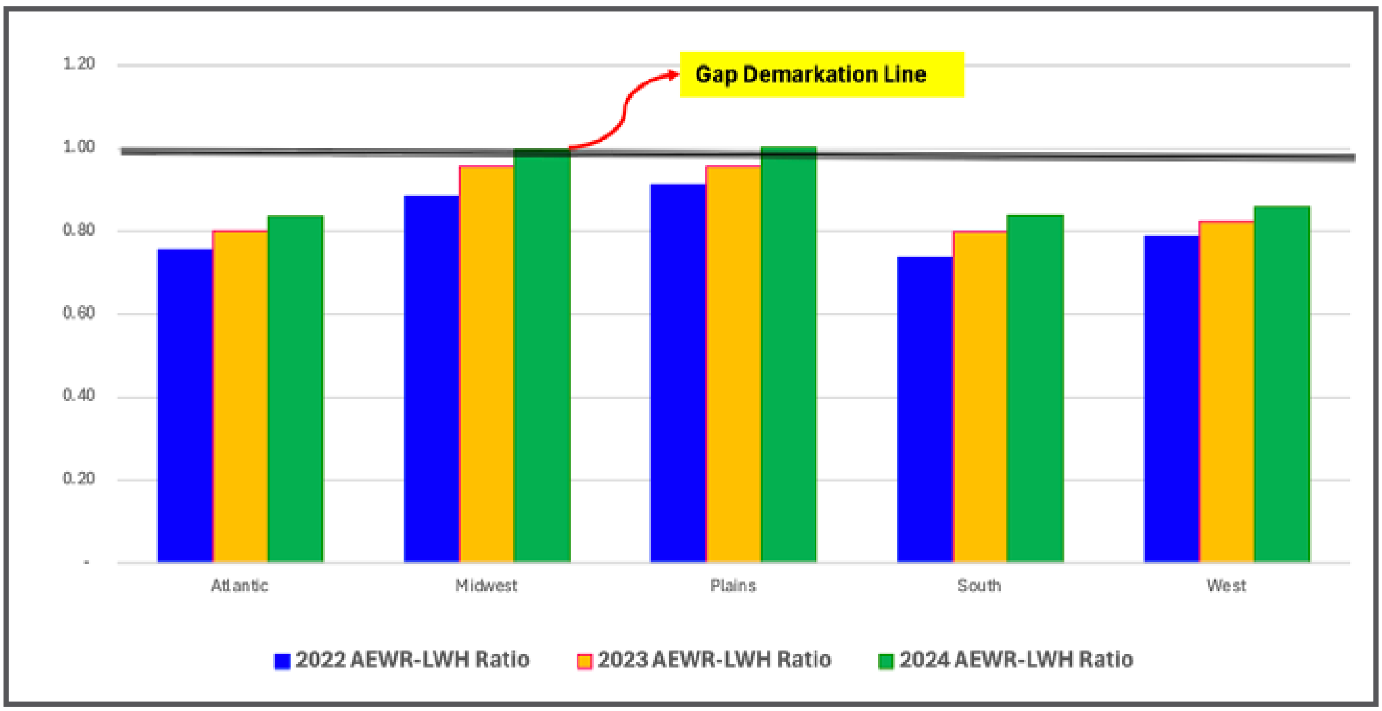

Figure 2. Adverse Effect Wage Rate to living wage (AEWR:LWH) ratios, regional averages, 2022–2024*

*Sources: Department of Labor Foreign Labor Application Gateway (FLAG) and Massachusetts Institute of Technology (MIT) Living Wage Calculator. Note: The regional groupings of U.S. states are as follows: ATLANTIC states include North Carolina, Virginia, West Virginia, Maryland, Connecticut, Massachusetts, New York, Vermont, New Hampshire, Maine, New Jersey, Rhode Island, and Delaware; MIDWEST states are Minnesota, Iowa, Wisconsin, Illinois, Missouri, Indiana, Ohio, Pennsylvania, and Michigan; PLAINS states are Nebraska, Kansas, Texas, North Dakota, South Dakota, and Oklahoma; WEST states include California, Washington, Oregon, Idaho, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Alaska, and Hawaii; and SOUTH states are Arkansas, Florida, Georgia, Louisiana, Mississippi, Alabama, Tennessee, South Carolina, and Kentucky

Figure 3. Declining net income levels due to AEWR increases in 2023 and 2024 under different scenarios of farm labor intensity for the U.S. production regions

Table 1. Regional Adverse Effect Wage Rates (AEWRs),[1] Levels, and Growth Rates, 2000–2024

Time Period	Atlantic	Midwest	Plains	South	West	Atlantic	Midwest	Plains	South	West
	Average AEWR ($ per Hour)					Minimum Wage ($ per Hour)				
2000–2009	8.49	9.10	8.40	7.84	8.62	6.11	5.59	4.84	5.32	5.98
2010–2018	10.86	11.78	11.65	10.05	11.30	8.08	7.61	7.46	6.82	8.01
2019–2022	13.91	14.69	14.30	12.01	14.76	10.53	8.64	7.91	8.52	10.20
2022	15.27	15.74	15.61	12.61	15.77	11.48	9.07	7.99	8.88	10.90
2023	16.34	17.24	16.51	13.87	16.60	12.12	9.42	8.38	9.13	11.41
2024	17.15	18.09	17.40	14.74	17.43	12.86	9.66	8.70	10.08	12.63
	Average Annual AEWR Growth Rates (%)					Average Annual Minimum Wage Growth Rates (%)				
2000–2009	3.53	3.76	3.94	3.39	3.47	3.48	3.83	3.34	3.84	3.90
2010–2018	2.53	2.41	2.97	2.25	2.30	2.69	1.53	3.38	1.66	2.61
2019–2022	5.84	5.59	5.48	3.64	4.76	5.71	3.09	0.58	5.13	4.76
2022–2024	6.00	7.22	5.58	8.13	5.13	5.82	3.18	4.34	6.66	7.70

Source: Department of Labor, Foreign Labor Application Gateway (FLAG)

Note: [1]The regional groupings of U.S. states are as follows: ATLANTIC states include North Carolina, Virginia, West Virginia, Maryland, Connecticut, Massachusetts, New York, Vermont, New Hampshire, Maine, New Jersey, Rhode Island, and Delaware; MIDWEST states are Minnesota, Iowa, Wisconsin, Illinois, Missouri, Indiana, Ohio, Pennsylvania, and Michigan; PLAINS states are Nebraska, Kansas, Texas, North Dakota, South Dakota, and Oklahoma; WEST states include California, Washington, Oregon, Idaho, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Alaska, and Hawaii; and SOUTH states are Arkansas, Florida, Georgia, Louisiana, Mississippi, Alabama, Tennessee, South Carolina, and Kentucky.

Table 2. Adverse Effect Wage Rate (AEWR) and Living Wage Per Hour (LWH) Ratios, by Region						
Region	Adjusted Ratios			Unadjusted Ratios		
	2022	2023	2024	2022	2023	2024
Atlantic	0.76	0.80	0.84	0.65	0.69	0.73
Midwest	0.88	0.96	1.00	0.76	0.83	0.87
Plains	0.91	0.96	1.00	0.78	0.83	0.87
South	0.74	0.80	0.84	0.61	0.67	0.72
West	0.79	0.82	0.86	0.68	0.71	0.75

Sources: Department of Labor Foreign Labor Application Gateway (FLAG) and Massachusetts Institute of Technology (MIT) Living Wage Calculator

Note: [1] The regional groupings of U.S. states are as follows: ATLANTIC states include North Carolina, Virginia, West Virginia, Maryland, Connecticut, Massachusetts, New York, Vermont, New Hampshire, Maine, New Jersey, Rhode Island, and Delaware; MIDWEST states are Minnesota, Iowa, Wisconsin, Illinois, Missouri, Indiana, Ohio, Pennsylvania, and Michigan; PLAINS states are Nebraska, Kansas, Texas, North Dakota, South Dakota, and Oklahoma; WEST states include California, Washington, Oregon, Idaho, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Alaska, and Hawaii; and SOUTH states are Arkansas, Florida, Georgia, Louisiana, Mississippi, Alabama, Tennessee, South Carolina, and Kentucky

Table 3. Farm Cash Receipts and Labor Costs, U.S. Fruit and Vegetable Sector, 2018–2024							
Financial and Labor Measures	2018	2019	2020	2021	2022	2023F	2024F
Gross Cash Receipts, $'000							
Fruits and Tree Nuts	29,350,820	29,194,440	27,832,041	30,641,709	26,913,586	26,801,455	27,564,587
Vegetables and Melons	18,678,919	19,097,959	21,053,596	19,471,584	25,205,469	22,740,681	22,710,417
Labor Cost Estimate, $'000[1]	20,679,437	20,776,682	20,945,857	21,577,403	22,193,301	21,905,676	22,801,663
Fruits and Tree Nuts	13,207,869	13,137,498	12,524,418	13,788,769	12,111,114	12,487,484	13,162,242
Vegetables and Melons	7,471,568	7,639,184	8,421,438	7,788,634	10,082,188	9,418,192	9,639,421
Certified H-2A Workers	242,762	257,667	275,439	317,619	371,619	378,513	375,066
AEWR ($ per Hour)	12.47	13.25	13.99	14.62	15.56	16.13	16.98
Total H-2A Wages per Hour ($)	3,027,242	3,414,088	3,853,392	4,643,590	5,782,392	6,105,415	6,368,621
Fruits and Veg Sector's H-2A Share[2]	1,331,987	1,502,199	1,695,492	2,043,180	2,544,252	2,686,382	2,802,193

Source: USDA-ERS, 2024

Note: [1] The labor cost figures for fruit and vegetable farms are calculated based on the findings of Castillo et al. (2021) that labor costs account for 45% and 40%, respectively, of these industries' gross cash receipts.

[2] Castillo et al. (2021) estimates that foreign workers comprise 44% of all hired labor. We assume here that all foreign workers are employed under the H-2A program.

Table 4. Estimated Effects of 2023–2024 AEWR Increases on 2024 Net Farm Income Levels and Margins, All U.S. States									
Net Income Effect under Two AEWR Growth Scenarios	**Incremental Labor Intensiveness (Additional Labor Share in Total Factor Input Costs)**								
	Base	5%	10%	15%	20%	25%	30%	35%	40%
A. Average State AEWR Growth between 2022 and 2024 (6.38%) [1]									
Labor's Share in Total Factor Payments (TFP)	44.10%	49.10%	54.10%	59.10%	64.10%	69.10%	74.10%	79.10%	84.10%
Adjusted TFP's VFP Share with AEWR Change[2]	17.58%	17.73%	17.88%	18.03%	18.18%	18.33%	18.48%	18.63%	18.78%
Adjusted Net Income Margin after AEWR Increments[3]	19.37%	19.22%	19.07%	18.92%	18.77%	18.62%	18.47%	18.32%	18.17%
Change in Net Income after AEWR Increments[4]	-6.42%	-7.15%	-7.88%	-8.61%	-9.34%	-10.06%	-10.79%	-11.52%	-12.25%
Change in Net Income Margin after AEWR Increments[5]	-1.33%	-1.48%	-1.63%	-1.78%	-1.93%	-2.08%	-2.23%	-2.38%	-2.54%
B. Highest State AEWR Growth between 2022 and 2024 (10.70%) [6]									
Labor's Share in TFP	44.10%	49.10%	54.10%	59.10%	64.10%	69.10%	74.10%	79.10%	84.10%
Adjusted TFP's VFP Share with AEWR Change[2]	18.48%	18.73%	18.99%	19.24%	19.49%	19.75%	20.00%	20.25%	20.50%
Adjusted Net Income Margin after AEWR Increments[3]	18.47%	18.22%	17.96%	17.71%	17.46%	17.21%	16.95%	16.70%	16.45%
Change in Net Income after AEWR Increments[4]	-10.77%	-11.99%	-13.21%	-14.44%	-15.66%	-16.88%	-18.10%	-19.32%	-20.54%
Change in Net Income Margin after AEWR Increments[5]	-2.23%	-2.48%	-2.74%	-2.99%	-3.24%	-3.49%	-3.75%	-4.00%	-4.25%

Notes:

[1] The state-level annual AEWR increases in 2023 and 2024 were 7.49% and 5.26%, respectively. The average of these two rates is 6.38%.

[2] In the USDA-ERS's forecasted 2024 estimates, the share of Total Factor Payments (TFPs) in Value of Farm Production (VFP) is 16.25%. In this row, this share is increased by the AEWR incremental effect for 2023 and 2024, further adjusted by additional H-2A fringe benefit costs for housing, meals, transportation, and other.

[3] Net income margins are adjusted by factoring in TFP's larger share of VFP.

[4] Net incomes are then recalculated using the adjusted net income margin in the previous row. The changes in absolute net income levels are based on deviations of the newly derived net income from the 2024 net farm income estimate of $116 billion.

[5] The changes in net income margins are based on the baseline 2024 net income margin of 20.70%, derived from total VFP of $560 billion and a net farm income estimate of $116 billion.

[6] Among all states, Georgia, Alabama, and South Carolina posted the highest average AEWR growth rate from 2022–2024 of 10.70%.

What Is Driving Non-Reported National Agricultural Statistics Service Yields?




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

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Abstract

The number of non-reported county yields by the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) is increasing. This article explores factors that impact county corn and soybean yields that are not reported by USDA NASS. Factors such as county, land coverage, and average farm size are used to explain the likelihood of a yield being reported. We find that counties that have a high number of acres concentrated in a few farms may not have a NASS yield reported due to NASS reporting requirements.

INTRODUCTION

The United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) is a government agency primarily focused on collecting and publishing agricultural statistics. One of the most utilized statistics collected by USDA NASS are annual county crop yield averages, which are frequently used by numerous groups such as government agencies, researchers, market analysts, and producers to provide much needed information about U.S. food and fiber production for policy development, farm insurance programs, farm disaster payment calculations, and decision-making, modeling the impact of several factors on production.

USDA NASS yields are collected as a part of an annual survey administered by NASS, which includes all states except Alaska and Hawaii. The county yield estimates are partially determined by self-reported average field-based estimates from producers. The survey, which starts in November and ends mid-January, is collected through mail, phone interviews, in-person interviews, and electronically via email, with most responses collected through phone calls. Statisticians review the survey results to identify and analyze outliers, such as extreme values, data entry errors, or inconsistencies with historical patterns, before inputting the data into a computer system for further analysis. Once outliers are corrected, the data is summarized by county and released (USDA NASS, 2023a).

However, over the last 15 years, there has been a decline in survey responses and the number of county yields being reported, which has resulted in growing concerns about yield accuracy (Johansson et al., 2017; Schnepf, 2017). The declining response rates create a challenge for USDA because it will not report yield data if the identity of the respondent can be revealed. Thus, NASS will not publish data for counties where small numbers of producers or acres in production may disclose the business of individual producers. NASS requires at least 30 producers or 25% of harvested acres to be reported to release a yield for a county. Figure 1 shows the increasing number of county level crops yields not reported by USDA NASS.

Along with researchers using this data (Lusk, 2016), the USDA relies on NASS surveys for a variety of payment calculations and policy recommendations. For example, NASS yields have been used to calculate Agricultural Risk Coverage-County (ARC-CO) payments, which compensate farmers when actual county crop revenue falls below guaranteed levels. Additionally, NASS yield data has been utilized in determining indemnity payments under the Federal Crop Insurance Program (Rejesus, Goodwin, and Coble, 2010) and in calculating farm disaster payments for programs like the Wildfire and Hurricane Indemnity Program (WHIP), where yield losses due to natural disasters are compared to historical averages to establish payment amounts. The rising number of missing NASS yields resulted in the Agricultural Improvement Act of 2018, switching from using NASS yields as the preferred yield for the ARC-CO payment calculations to USDA Risk Management Agency (RMA) yields as the primary yield used to calculate payments.

Rejesus, Coble, and Knight (2010) found that when reference yields for RMA were based on NASS data, it was not a true representation of yield information for the producers enrolled in the Federal Crop Insurance Program. As these yields were not updated, the problem increased due to technology in the agricultural sector improving (Rejesus, Coble, and Knight 2010). As a result of the study, it was recommended to use a reference yield calculation based on RMA yield (Rejesus, Coble, and Knight, 2010). Similarly, Li et al. (2020) examined the variability and reliability of a yield estimator based on NASS yields compared to RMA data for corn, soybeans, and wheat. Their paper used NASS and RMA yields from the years 1991-2015 to examine the feasibility of using RMA yields, rather than NASS yields to calculate ARC-CO payments. They found no major difference between the two yield values. Using RMA yield data for ARC-CO payments also resulted in less variability between nearby counties, possibly because RMA data reflects consistent, field-level records from insured farms.

While studies have attempted to estimate missing yield (Ishee, 2020; Park, Harri, and Coble, 2022), no study has attempted to try to understand the factors driving the missing yields. One hypothesis is that farm consolidation could result in fewer farms within a county, which might not meet the threshold for reporting yields. Therefore, the objective in this study is to determine if a county landscape and average size farm impact the likelihood of a NASS yield being reported. The results could directly impact how NASS could adjust its reporting requirement to adjust for larger and fewer farms in a county.

DATA

Data on county yield values for corn and soybeans across the U.S. was sourced from USDA NASS from 2011 to 2022 (USDA NASS, 2024). Additionally, land cover information was obtained from USDA CroplandCROS for all states (USDA, 2024). This land cover data from USDA CroplandCROS was then integrated with the USDA NASS yield data to form separate datasets for corn and soybeans. These datasets were refined by removing records of the observed crops that occupied less than a thousand acres in a county, as per USDA CroplandCROS data. Subsequently, data on the average farm size for each county, crop, and year was incorporated, derived from the USDA RMA summary of business statistics data (USDA RMA, 2024).

From USDA CroplanCROS, percentages of a county landscape by different land cover classification were calculated for the following classifications: soybeans, corn, cotton, pasture/hay (combined variable of the two classifications), developed (i.e., residential, commercial, or industrial uses), and forest. These percentages were calculated by taking the classifications and dividing them by the sum of all the classifications for a county. This calculation was done for each county by year. A USDA RMA summary of business statistics data was used to calculate a proxy of average farm size by dividing the total insured acres in a county for a given year by the number of insurance policies issued in that county during the same year, serving as an indirect measure of average farm size. A county was marked having a missing NASS yield value if the county had a thousand acres or more of the observed crop in a year according to USDA CroplandCROS and did not report a NASS yield that year.

Figure 2 displays the average corn acres planted by county from 2011-2022 for the U.S. from USDA CroplandCROS data. This figure shows that counties with greater corn acres are concentrated in the upper

Midwest and Northern Plains. Figure 3 displays the average soybean acres planted by county from 2011-2022 for the U.S. Soybean acres are concentrated along the Mississippi River, Northern Plains, and Midwest. Figure 4 shows the percentage of years where a NASS corn yield was reported by county from 2011-2022 for the U.S. A visual inspection between Figure 2 and Figure 4 suggests there is a relationship in yield report rate and corn acres planted. Figure 5 shows the percentage of years where a NASS soybean yield was reported by county from 2011-2022 for the US. The areas where counties have higher report rates are along the Mississippi River, Northern Plains, and Midwest, and this is also where soybean planted acres are more concentrated.

Table 1 displays the summary statistics of the variables observed for corn and used in the model, where the variables are the percent of the county that is in each crop, and average farm size is scaled. The summary stats indicate forest, and pasture/hay provide the most land cover in counties used for the corn analysis. On average, corn acres cover about 12% of the land within a county, and soybeans cover 11% of the land within a county; the average corn farm size was 134 acres. The summary statistics of the variables observed for soybeans are displayed in Table 2. The percentage of land cover in a county was similar for soybeans, with both corn and soybeans covering 13% of the land area for the soybean data. The average soybean farm size was 148 acres, and according to 2022 USDA Census data, the average harvested crop farm was 158 acres in 2022 (USDA National Agricultural Statistics Service, 2022), which is slightly higher than our average in our data.

METHODS

A logit model was utilized to determine how a county's landscape and the average size of corn and soybean farms influence the probability of a NASS yield being reported. A logit model is a type of statistical analysis used to predict the likelihood of an outcome when the dependent variable is binary. In this case, we define a NASS yield as being equal to 1 and 0 if it is not reported. The findings are expressed in terms of odds ratios, which quantify how a change in an independent variable affects the odds of a NASS yield being reported, either increasing or decreasing these odds by a specific percentage. This approach is particularly suited for binary outcomes like this model, where the independent variables include the percentage of the county that is in soybean acres, in corn acres, in cotton acres, in pasture and hay acres, in developed acres, and in forest acres; the average farm size proxy scaled by a thousand; the average farm size proxy squared scaled by a thousand; and a fixed effect for state and year. The model and average marginal effects were calculated in R using the margins package.

RESULTS

The results from the logistic regression analysis aimed to explore the impact of county landscape and average farm size on the likelihood of a NASS yield being reported are summarized in Table 3.

In the case of corn, the proportion of county landscape used for corn production exhibited a strong positive relationship ($p < .001$) with the likelihood of a NASS corn yield being reported. Additionally, the proportion of county landscape dedicated to corn production, along with percentages of landscape in cotton and pasture/hay, average farm size, and average farm size squared, all showed significant relationships ($p < .001$). Similarly, in the soybean model, the proportion of county landscape allocated to soybean production had a significant relationship ($p < .001$). In both models, the percentage of the county that was developed was not significant for a NASS yield being reported. In both models, state and year fixed effects were incorporated into the model to control variations across different states and years. The average marginal effects are shown in Table 4. For example, a 1% increase in the percentage of the landscape in corn results in a 0.82% increase in the likelihood of a NASS corn yield. For the soybean model, a 1% increase in the percentage of the landscape in soybeans results in a 0.86% increase in the likelihood of reporting a NASS soybean yield.

In both models, the proxy of average farm size and the proxy of average farm size squared were found to be significant, indicating a positive influence on the likelihood of reporting a NASS yield until a certain threshold. Figure 6 illustrates the predicted probability curve, showing that for corn, the likelihood starts decreasing after 228.33 acres, and for soybeans, after 253.13 acres. This could indicate farm consolidation could negatively impact the likelihood of NASS yields being reported, which would suggest that farms continue to consolidate USDA NASS and revisit their criteria of reporting yields in a county to avoid not reporting counties with a reportable level of acres but not enough farms.

CONCLUSION

The increasing number of counties non-reporting a USDA NASS yield is increasing and is causing concern for researchers, government agencies, and market participants. This research seeks to discover factors that are associated with corn and soybean yields not being reported. By investigating the impact of county landscape and average farm size on the likelihood of reporting NASS yields for corn and soybeans, this study contributes valuable insights to the existing literature.

The results of the logit model indicate that a county's landscape impacts the likelihood of a NASS yield being reported. Counties that have a higher percentage of their landscape in agricultural production are more likely to have a NASS yield reported. It also indicates that average farm size plays a role in the likelihood of a NASS yield being reported as well. Counties that have a high number of acres concentrated in a few farms may not have a NASS yield reported, due to large farm size resulting in the county having fewer than 30 producers or 25% of harvested acres responding to the survey. This could continue to be an issue as we continue to see farm consolidation across the U.S. Having a county that produces many acres for either crop or not reporting a yield could result in a reporting bias, which could occur because gaps in a county NASS yield history impact the historical county average. One county not receiving enough survey responses could also impact state and national averages as well.

Addressing the challenges posed by the increase in non-reported yields is crucial for policymakers, researchers, and market participants to make informed decisions and foster a more resilient and sustainable agricultural sector. Continued efforts to improve data collection methods and enhance the accuracy of yield reporting are imperative to ensure the reliability of NASS data.

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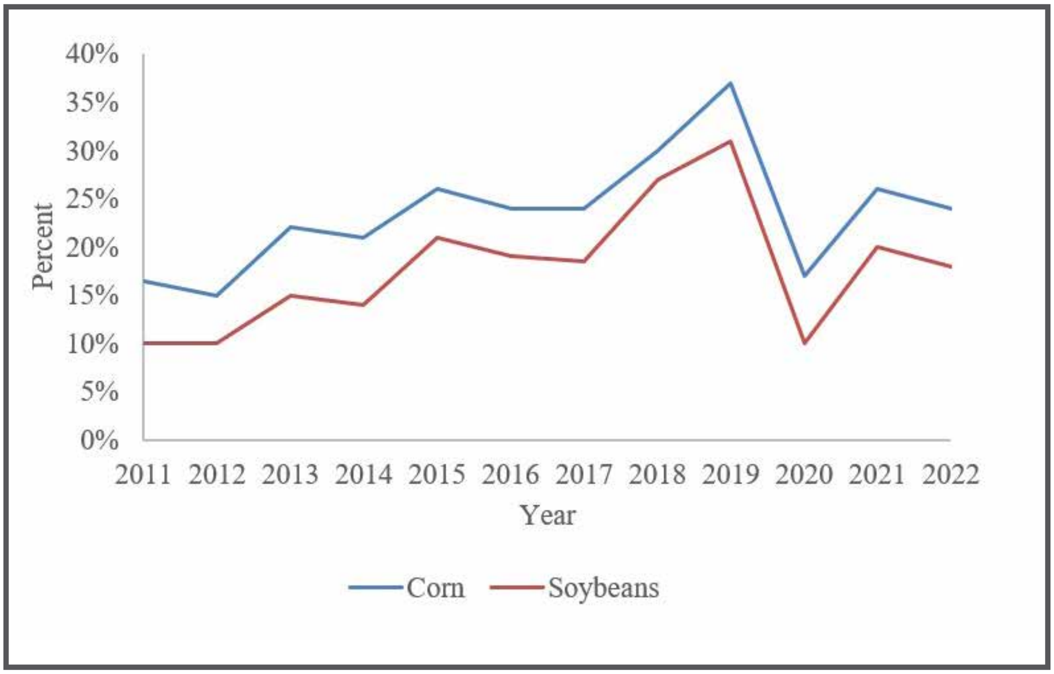

Figure 1. Percentage of missing NASS county corn and soybean yields response, 2011–2022

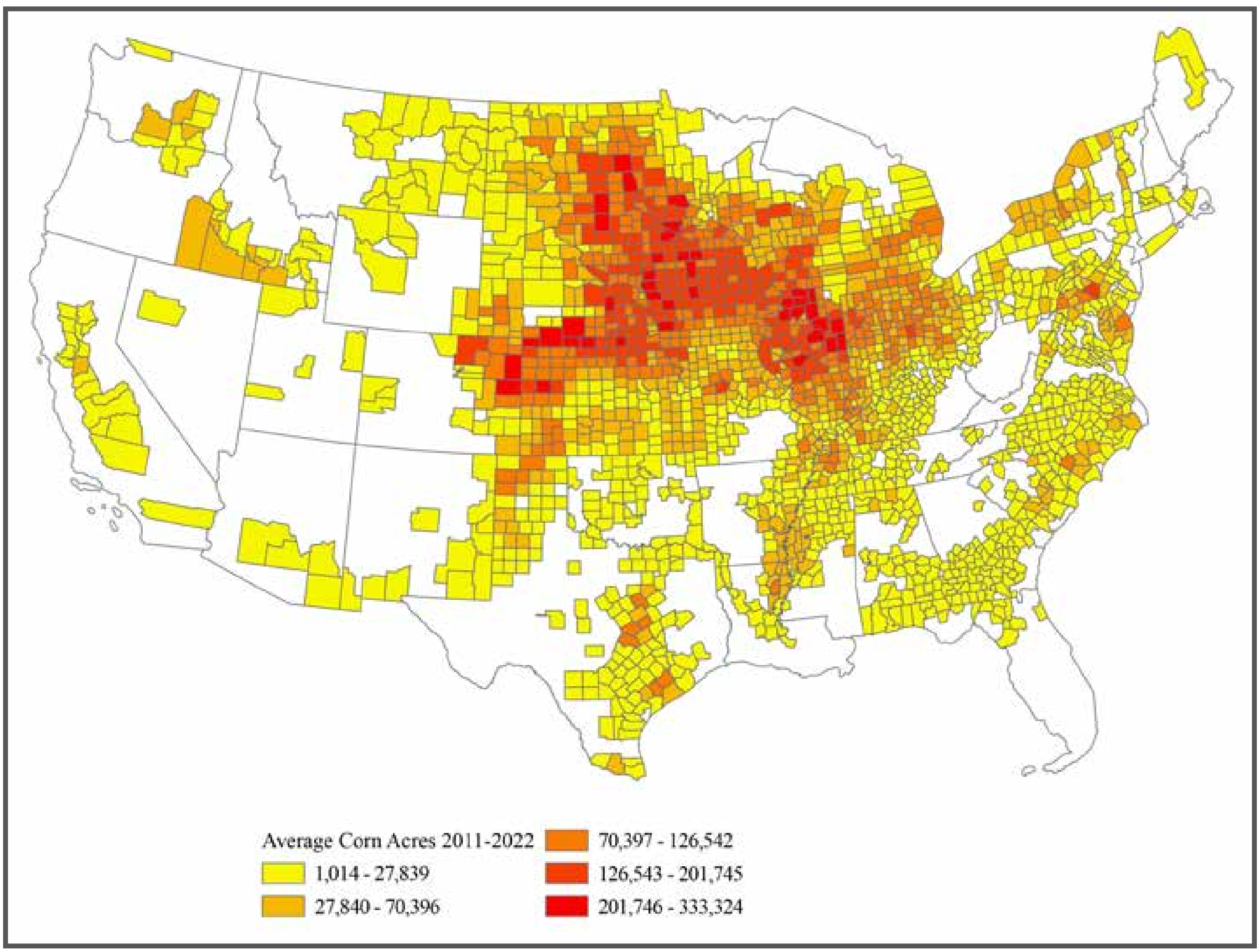

Figure 2. Average planted corn acres 2011–2022 USDA CroplandCROS

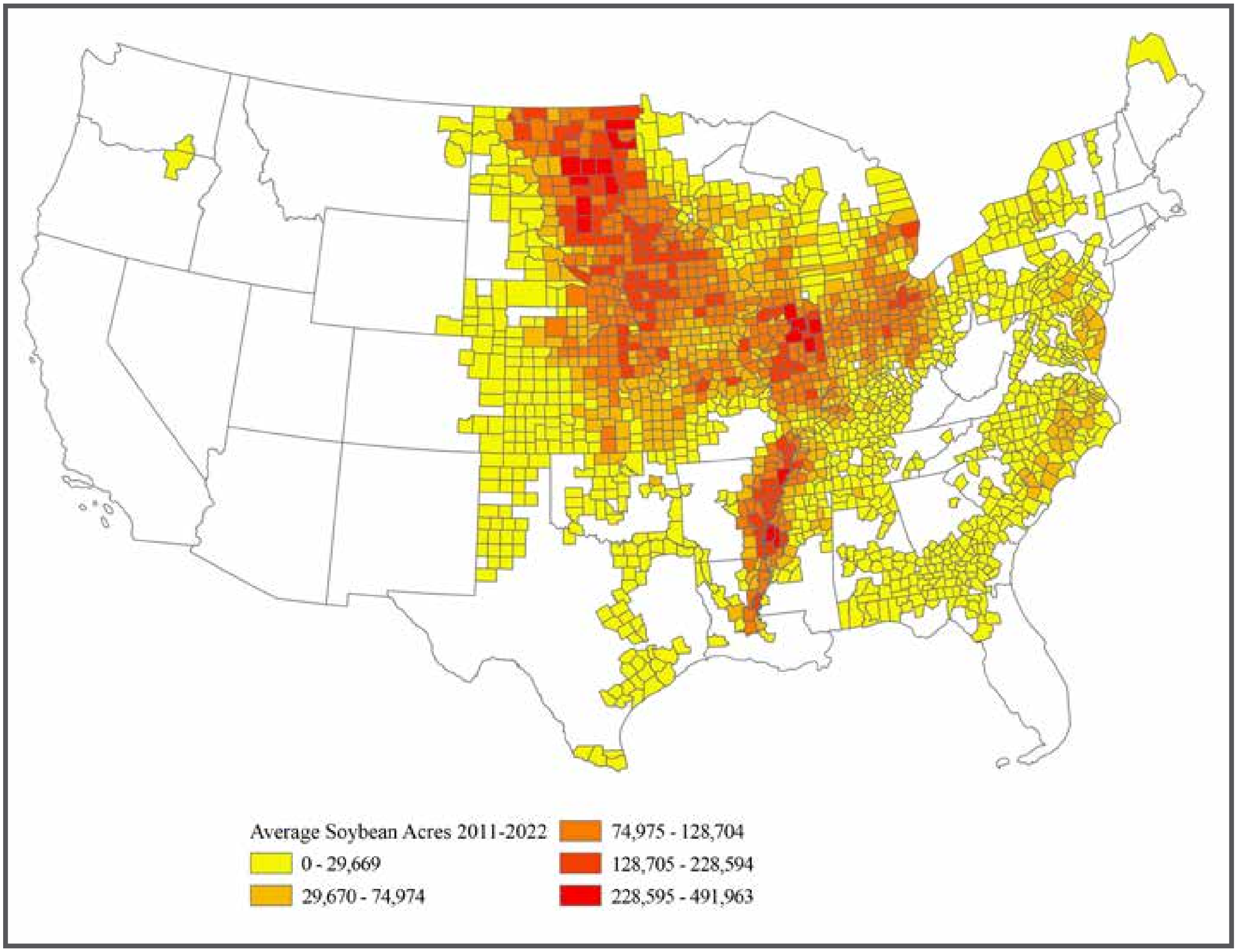

Figure 3. Average planted soybean acres 2011–2022 USDA CroplandCROS

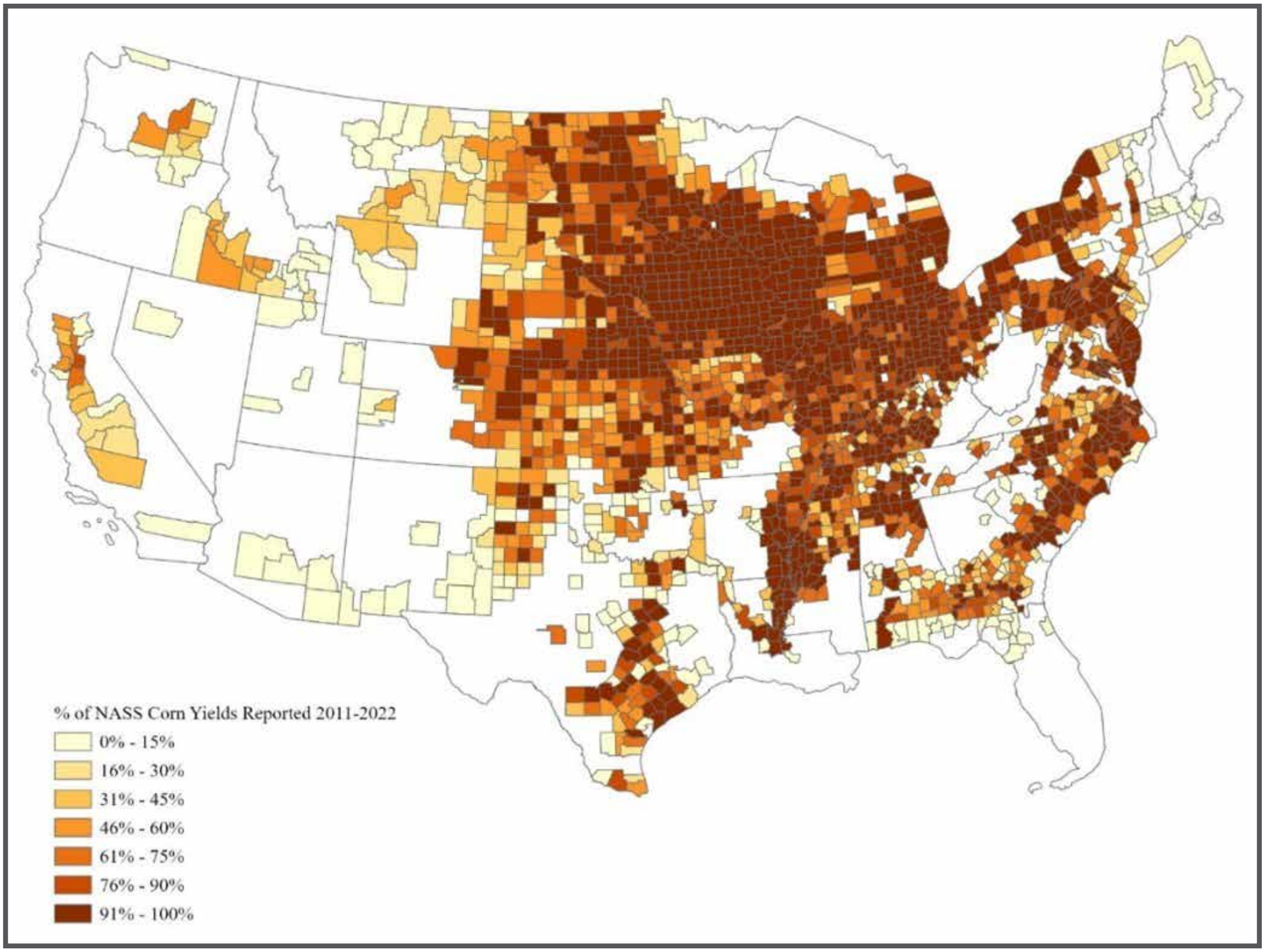

Figure 4. Percentage of NASS corn yields reported 2011–2022

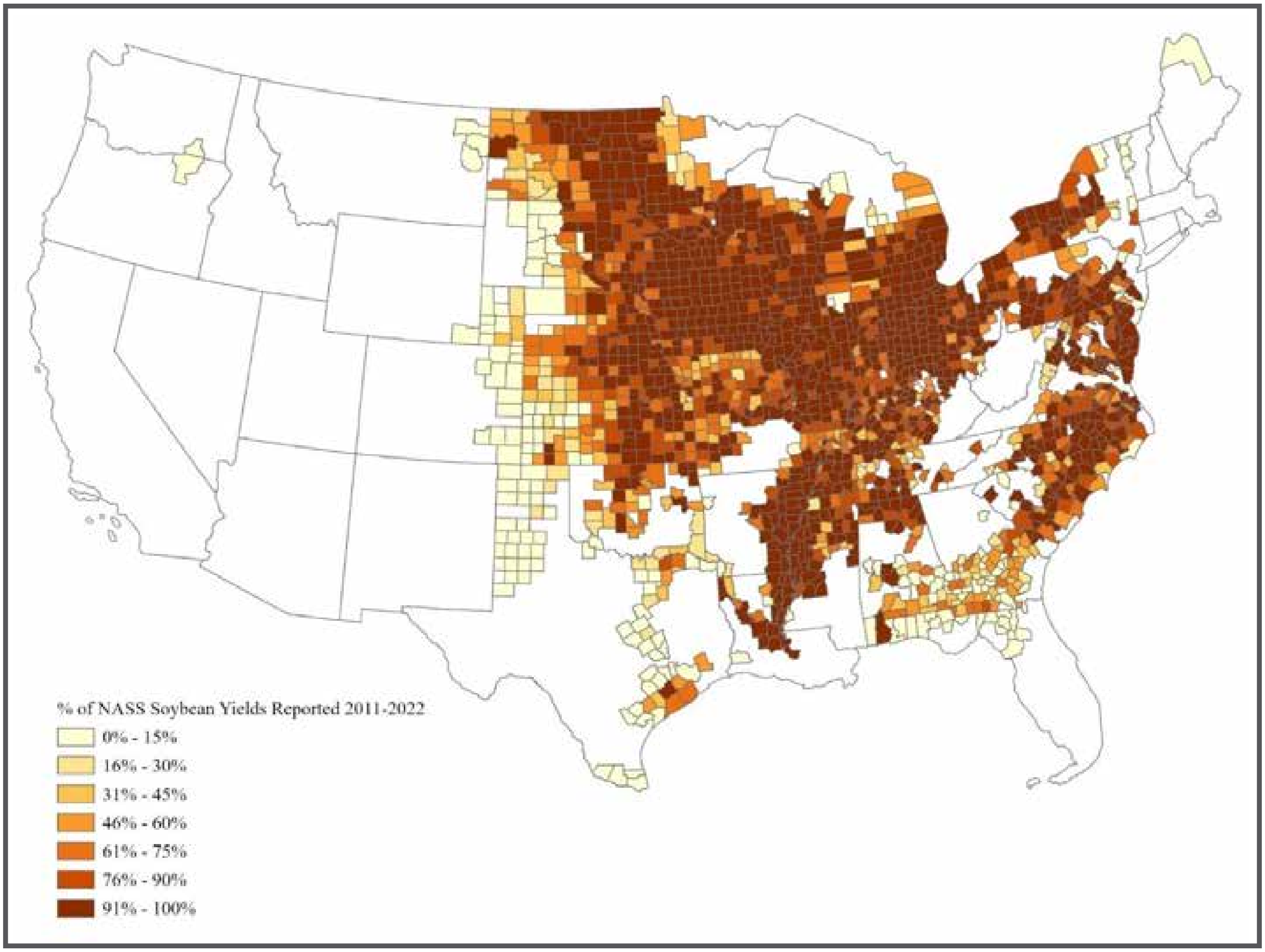

Figure 5. Percentage of NASS soybean yields reported 2011–2022

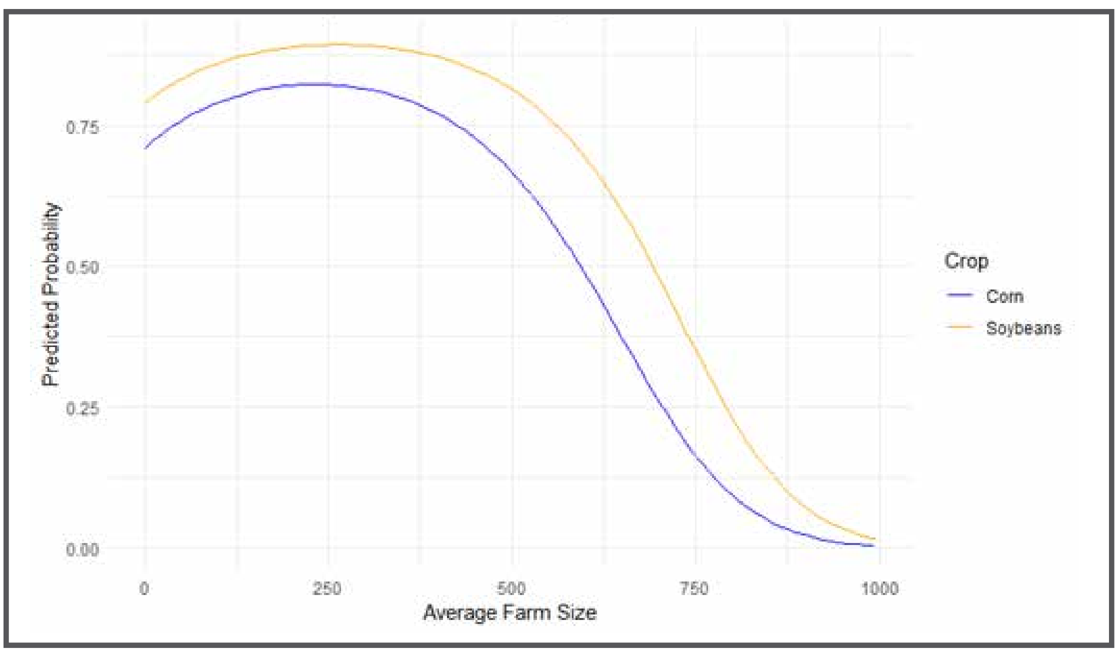

Figure 6. Predicted probability of a NASS yield being reported in a county by farm size

Table 1. Summary Statistics of Independent Variables for Corn Model from 2011 to 2022				
Variable	**Average**	**Standard Deviation**	**Minimum**	**Maximum**
Percentage of County in Beans	0.11	0.13	0.00	0.68
Percentage of County in Corn	0.12	0.14	0.00	0.63
Percentage of County in Cotton	0.01	0.05	0.00	0.71
Percentage of County in Pasture or Hay	0.22	0.19	0.00	0.97
Percentage of County that is Developed	0.08	0.08	0.00	0.85
Percentage of County in Forest	0.23	0.22	0.00	0.83
Average Farm Size (in 1,000 acres)	0.13	0.08	0.00	1.17

Table 2. Summary Statistics of Independent Variables for Soybean Model from 2011 to 2022				
Variable	**Average**	**Standard Deviation**	**Minimum**	**Maximum**
Percentage of County in Beans	0.13	0.13	0.00	0.68
Percentage of County in Corn	0.13	0.14	0.00	0.63
Percentage of County in Cotton	0.01	0.04	0.00	0.70
Percentage of County in Pasture or Hay	0.20	0.17	0.00	0.97
Percentage of County that is Developed	0.08	0.08	0.00	0.85
Percentage of County in Forest	0.24	0.22	0.00	0.83
Average Farm Size (in 1,000 acres)	0.14	0.09	0.00	1.33

Table 3. Logit Model Results for NASS Yield Reporting by County Landscape		
	Corn	**Soybeans**
Variable	**Estimate**	**Estimate**
Intercept	1.013***	1.31***
Percentage of County in Beans	2.189***	7.486***
Percentage of County in Corn	6.144***	1.341**
Percentage of County in Cotton	1.878***	3.886**
Percentage of County in Pasture or Hay	0.918***	0.5*
Percentage of County that is Developed	-0.013	0.511
Percentage of County in Forest	-0.065	-0.079
Average Farm Size (in 1,000 acres)	5.48***	5.569***
Average Farm Size (in 1,000 acres) Squared	-0.012***	-0.011***

*,**, *** represent significance at the 10%, 5%, and 1% levels, respectively.

Table 4. Average Marginal Effects of NASS Yield Reporting		
	Corn	**Soybeans**
Variable	**Estimate**	**Estimate**
Percentage of County in Beans	0.2904***	0.8602***
Percentage of County in Corn	0.8149***	0.1613**
Percentage of County in Cotton	0.2492***	0.5548**
Percentage of County in Pasture or Hay	0.1217***	0.0629*
Percentage of County that is Developed	-0.017	0.030
Percentage of County in Forest	-0.0086	-0.015
Average Farm Size (in 1,000 acres)	0.7269***	0.00007***
Average Farm Size (in 1,000 acres) Squared	-0.016***	-0.0013***

*,**, *** represent significance at the 10%, 5%, and 1% levels, respectively.

An Examination of the Use of Rented Land by Kansas Farmers

By Gregory Ibendahl

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Abstract

Renting farmland is an important topic to farmers as it complements a typical farm's largest asset. There are many advantages to owning farmland, but purchased farmland will seldom cashflow. Thus, most farmers have additional rented crop acres. Over the last 50 years, both profitability and financial risk from farming have increased, and this paper examines whether these changing agricultural conditions have impacted the percent of farmland rented. An exploratory analysis of Kansas data shows the land rental percentage has remained constant since the end of the 1980s farm crisis with the median farm renting 75% of its cropland acres. These results should provide guidance about the demand for rented farmland.

INTRODUCTION

Crop farmers have two ways to build an acreage base for their farming operation: own their land or rent it. Ownership provides many advantages, such as land control, capital appreciation, and pride of ownership. With land ownership, a farmer never has to worry about losing a lease to another farmer and can make all the management decisions without answering to a landlord. In addition, land typically appreciates each year and is a good hedge against inflation. However, as shown in Oltmans (1995), land will not cashflow. Thus, most farmers need the income from additional rented acres to help make the principal and interest payments on their land mortgages. This article examines the mix of rented and owned land by Kansas farmers to determine if the use of rented land has changed over time in response to rising land values and changes in farm profitability.

According to the U.S. Department of Agriculture's website (https://quickstats.nass.usda.gov), the average value of cropland in Kansas has increased from $649/acre in 1997 to $3,300/acre in 2024. During this same period and based on Kansas Farm Management Association (KFMA) grain farms (KFMA, 2024), average net farm income has varied from a low of $11,000 in 2015 to a high of $355,000 in 2021. The average number of crop acres across KFMA grain farms increased from 1,200 acres in 1997 to 1,800 acres in 2023. Although KFMA farms are not an exact representation of Ag Census farms (fewer very small farms and very large farms), the data does closely track changes in Economic Research Service (ERS) yearly net farm income (Ibendahl, 2021).

Both average net farm income and income volatility (financial risk) have increased over time for Kansas farmers. Comparing the five-year period starting from 1997 to the five-year period ending in 2023, average net farm income has increased from $37,000 to $190,000. However, the standard deviation of net farm income has also increased from $15,000 to $103,000.

The increase in land values since 1997 has been countered by the increase in average net farm income. Land values have increase 400%, while the five-year average of net farm income has also increased by 400%. However, the coefficient of variation has increased from 0.39 to 0.54, indicating that the relative financial risk has increased.

With this evidence of increased financial risk to farming, farmers might be increasing their use of rented land to provide a higher level of liquidity to meet periods of lower net farm income. This article examines the distribution of cropland rental percentages for all the KFMA grain farms at five-year intervals to determine if rented land has become a larger proportion of a farmer's crop acreage base. These results should provide guidance about the demand for rented farmland.

BACKGROUND

The question of whether farmers should buy or rent their farmland has been studied for a long time. Reiss (1972) presented an analysis comparing the costs of purchasing land against the expected capital benefits from a purchase, using a sample farm approach to show that many of the benefits of owning land occur in the future. Some of the important issues a farmer should consider are the opportunity cost of capital, the mortgage interest rate, the land price relative to the net rent, and the variability of future prices and rents.

Edwards (2015) used an example farm approach similar to Reiss and found that much of the financial feasibility of purchasing farmland depends on the financial position of the farmer/borrower. Borrowers with enough cash to make a larger downpayment and who have other sources of revenue are better able to make a land purchase feasible. These factors are in addition to the purchase price and interest rate.

However, even if a farmer concludes that owning is the best choice, cashflow issues arise with land purchases. As shown in Oltmans (1995), farmland will seldom generate sufficient income to meet the cashflow requirements for principal and interest payments. Because land is non-depreciable and often appreciates, much of the return to owning land is based on land appreciating, thus, land could be a very profitable investment, yet still not be able to cashflow. This cashflow requirement would require a farmer to have rented land or have sufficient cash already available to contribute to loan payments.

While much of the literature has examined the land purchase versus land renting choice in terms of profitability and cashflow, some research has explored other factors, such as soil degradation and erosion. Leonhardt et al. (2021) investigated whether farmers used different conservation practices on rented land and found no differences between rented and owned cropland in the application of different soil conservation practices. However, this result could be because the rental arrangements in the samples studied were all secure, long-term arrangements.

The ratio of farmland price to cash rent price can be important when examining a farm's use of rented land. If farmland prices are high relative to cash rent prices, farmers are more likely to rent ground rather than purchase ground. Baker et al. (2014) examined the rise in farmland prices from the early 2010s and found the farmland price to cash rent ratio was at historic highs and cautioned investors about purchasing farmland as a risk strategy in a portfolio of assets. However, farmland values increased 4.6% on a compounded annualized growth rate from 2017 to 2022 and increased 7.4% in 2022 (ERS, 2025). Thus, farmland was a profitable investment at the time of the Baker et al. paper.

DATA

This study uses data from the KFMA, a program that has been helping farmers since the 1930s and that has computerized farm records back to the early 1970s. There are currently around 2,000 farms in the KFMA system, and in any given year, about half of those farms will have records that are useable for research, teaching, and Extension analysis. However, the number of farms with usable data has declined over time as farms have gotten larger. In 1980, there were 2,500 farms with usable data, but in 2023, there were just 850 farms. There is also some evidence of continuity among the KFMA farms. Of the set of farms in 2023, about half have at least 10 years of continuous farm data.

KFMA farms work with an economist to collect financial and production data. Farms that are certified usable will have a valid income statement and balance sheet. While the focus is on collecting financial information, some production information is also collected, including the acres of each crop grown as well as the acres rented and own. The land rent percentage is calculated by dividing the number of rented crop acres by the total number of crop acres.

One limitation of the KFMA rental data is the lack of information about the type of lease. Share leased and cash leased land are both lumped together as rented land, and although this grouping does not affect the analysis shown here, the type of lease would help with other analyses. Any analysis of how renting farmland affects the risk levels of tenants and landlords is difficult to measure with KFMA data because cash leasing puts all the risk on the tenant while share leasing splits the risk between tenant and landlord. Also, the risk aversion level of tenants and landlords will dictate whether a cash or share lease is used.

To help provide a clearer picture of how rented land is used, only grain farms are used in this analysis. About two-thirds of KFMA farms fit into a grain farm category. Note that the KFMA uses labor hours as a mechanism to separate farms into farm types, so there is likely a small amount of beef production on many grain farms.

ANALYSIS

For the analysis in this study, the percent of rented cropland was calculated for every grain farm since 1972, the earliest date when KFMA records were computerized. The first part of the analysis shows the median percentage of farmland rented each year (Figure 1). The median percentage of farmland rented is the midpoint of percent rented acres when the farms are ranked from the lowest percent of rented acres to the highest percent of rented acres.

The blue dashed line in Figure 1 shows the median rental percentage by region where the rental percentage is the percent of rented crop acres divided by total crop acres. Breaking the analysis into regions can be important because farming practices change considerably from East to West across the state. The Eastern part of the state receives rainfall that is close to the rainfall levels in Iowa and Missouri, and Eastern Kansas follows similar production practices. In the Western part of the state, rainfall drops to well under 20 inches, and fallowing land is common. More wheat and grain sorghum are grown in the Eastern part of the state, where corn and soybeans are the primary crops without the use of fallow land.

While the Central and Eastern parts of the state have several hundred KFMA farms each, the Western part of the state has less than 100 KFMA farms. In addition, these Western farms are much larger than in the other parts of the state, the size difference reflecting the number of acres needed to make a living when lack of rainfall constrains yields. As a result of fewer farms in the analysis, there is more variation in the calculated rental percentages in Western Kansas.

As Figure 1 shows, the median land rent percentage is between 70% and 80% in all three regions and across time except for the late 1970s and early 1980s. At the start of the KFMA dataset, the land rent percentage was closer to 60%. This increase in rental percentage reflects the same period as the 198's farm crisis and the drop in land values during that time.

Figure 1 also shows the percent of farms not renting (red, solid line in the figure), which has remained around 10% over the entire database history. Western Kansas is the exception, but this variability is likely a small data issue.

The second part of the analysis developed a CDF (Cumulative Distribution Function) graph of rental percentages at each five-year interval starting from the most recent year of data (2023). A CDF function shows the rental percentage of each farm for that year, with the rental percentages sorted from low to high and then plotted on the graph. This analysis is shown in Figure 2. At any given rented acre fraction (X-axis values), a cumulative distribution shows the percentage of farms (Y-axis values) that have that fraction of rented acres or lower. The 50-percentile point (from the Y-axis) is the median level of the fraction of rented acres. A cumulative distribution shows a line from 0 to 100% (Y-axis) to represent the entire distribution of farms.

A CDF shows the probability the random variable X will take a value less than or equal to X. In Figure 2, the random variable is the rented acres fraction shown along the horizontal X-axis, with the probability of obtaining that rented acres fraction or less shown on the vertical Y-axis. The median rented acre fraction of how much land a Kansas farmer rents corresponds to the 50% point on the Y-axis, so, for example, in 2018, the median Kansas farm rented about 75% of its cropland.

The other way to interpret this CDF graph is to start from a point along the X-axis and then find the percent of farms with that level of rented ground or less. The red numbers in Figure 2 show this approach for farms that rent 50% of their cropland or less—for example, in 2018, 24% of the farms rent less than half their cropland. The right edge of each CDF helps show the percent of farms renting all their cropland—for example, in 2018, at slightly less than the 1.0 point along the X-axis (nearly 100% rented land), about 85% of farms have at least some acres of owned land. This can also be restated as 85% of farms have up to 100% of rented land but not 100% exactly. That means 15% of farms are farming with all their crop acres rented.

The left edge of the CDF shows the percent of farms not renting any cropland. The blue line stops before reaching zero, so this endpoint is the percent of farms not renting. The percent of farms not renting can be read from the CDF and is also shown in Figure 1 (the red, solid line).

An analysis of farmland renting by size of farm and age of principle operator is shown in Figures 3 and 4. Although the median rental percentage has not changed greatly since the end of the 1980s farm crisis, there are some farm size and operator age differences.

Figure 3 examines the percent of farmland rented by farm size. KFMA farms are divided into three equally sized groups based on the number of crop acres, and as might be expected, smaller farms own more of their crop acres than larger farms. For all three farm size groups, renting increased in response to the 1980s farm crisis and then leveled out.

Figure 4 examines the percent of farmland rented by age of the principal operator. As in Figure 3, KFMA farms are divided into three equally sized groups based on operator age, and the age breakdown is again as expected with younger farmers renting more of their land than older farmers. The younger and middle-aged farmers show a similar pattern to the other figures, with an increase in renting from the farm crisis and then a leveling out in the percent of farmland rented. The oldest farmer group is an exception to this trend with a large drop in rented land from 1987 to 1992 before beginning an increasing trend in the percent of rented farmland. However, this difference could be a data issue as farms do move in and out of the KFMA program.

CONCLUSIONS

Although this analysis is more exploratory than econometric, several observations can be made from Figures 1 and 2. First, cropland control changed during the 1980s farm crisis, with the percent of rented land increasing from 60% to 80% during this period, but since the mid-1980s, the percent of rented land has stayed within a narrow band in both Central and Eastern Kansas. Western Kansas is an outlier, likely due to the smaller number of farms in the KFMA program.

The 1980s farm crisis was a period of low profitability and high interest rates. It was also a period where land values declined for the first time in history, but the 1980s were not only a crisis period for farmers but also for banks that were heavily invested in agriculture. This is when the Farm Financial Standards Council was implemented to help create standards for farm accounting and evaluation. Banks moved away from farm lending based solely on solvency criteria to lending that also evaluated farm profitability. Thus, farmers were less able to borrow money to purchase farmland. More restrictive lending combined with lower per acre profitability likely led to the increase in renting during the 1980s.

The second observation based on Figures 1 and 2 is how consistent the rented cropland percent has remained since the farm crisis of the 1980s ended. Not only has the median percent rented acres remained in a narrow range as shown in Figure 1, but the entire distribution of farms in a specific year is visually consistent as shown in Figure 2. The percent of farms not renting is typically less than 10%, while the percent of farms renting all their cropland is between 15% to 25%. Figure 2 also shows the percent of farms renting half their cropland or less has remained near 25% during each five-year interval over the last 50 years.

Finally, there are renting differences based on farm size and operator age that are consistent with expectations about renting with younger farmers renting more of their land than older farmers. Older farmers typically have a bigger equity base and can afford to buy more of their crop land. Also, farmers do have a limited amount equity, so it is not surprising that the largest farms need to rent a greater percentage of their cropland to become a large farm.

DISCUSSION

The increase in rented land during the 1980s farm crisis is readily explainable because of tighter lending standards and lower profitability. However, since then, there have been periods of very low profitability as well as periods of very high profitably. Despite these changing conditions, the percent of rented land has remained within a limited range with visually similar distributions. Only the 1980s farm crisis shows any real changes occurring with the percent of rented ground. The older farmer group could be an exception to this consistent renting percentage, or it could be a data issue as the age of the principal operator changes when a long-term KFMA farm moves to a new generation.

For discussion, here are some ideas that merit further analysis. First, does it take a land price decrease before farmers are willing to move to a higher level of rented ground? Farmers perceive many advantages to owning land, including the typical yearly capital appreciation. When land prices decline, this advantage goes away making rented land look more attractive.

Second, the relative financial risk to farming has increased as discussed in the introduction about the increase in the coefficient of variation. This increase in financial risk means a farmer's net income is subject to more year-to-year variation, but why has this risk increase not also increased the percent of land rented? It may be possible the stickiness of rental arrangements and the difficulty of quickly changing a farm's land control structure has kept the land rent percent distribution from changing very quickly or changing very much.

Third, there have been periods where the land price to cash rent ratio has changed during the last 50 years, but these changes do not show up in a visual inspection of land rent percentages. Perhaps these changes are just short term and revert to a given mean after a time? This would explain why the land rent percent does not show any changes given these changes are sticky.

The last discussion point is about how appraisers should approach evaluating land. Do the land price and land rental markets have self-correcting mechanisms in place to keep them in balance? The consistency in how farmers maintain the same level of rented ground through time suggests that is the case.

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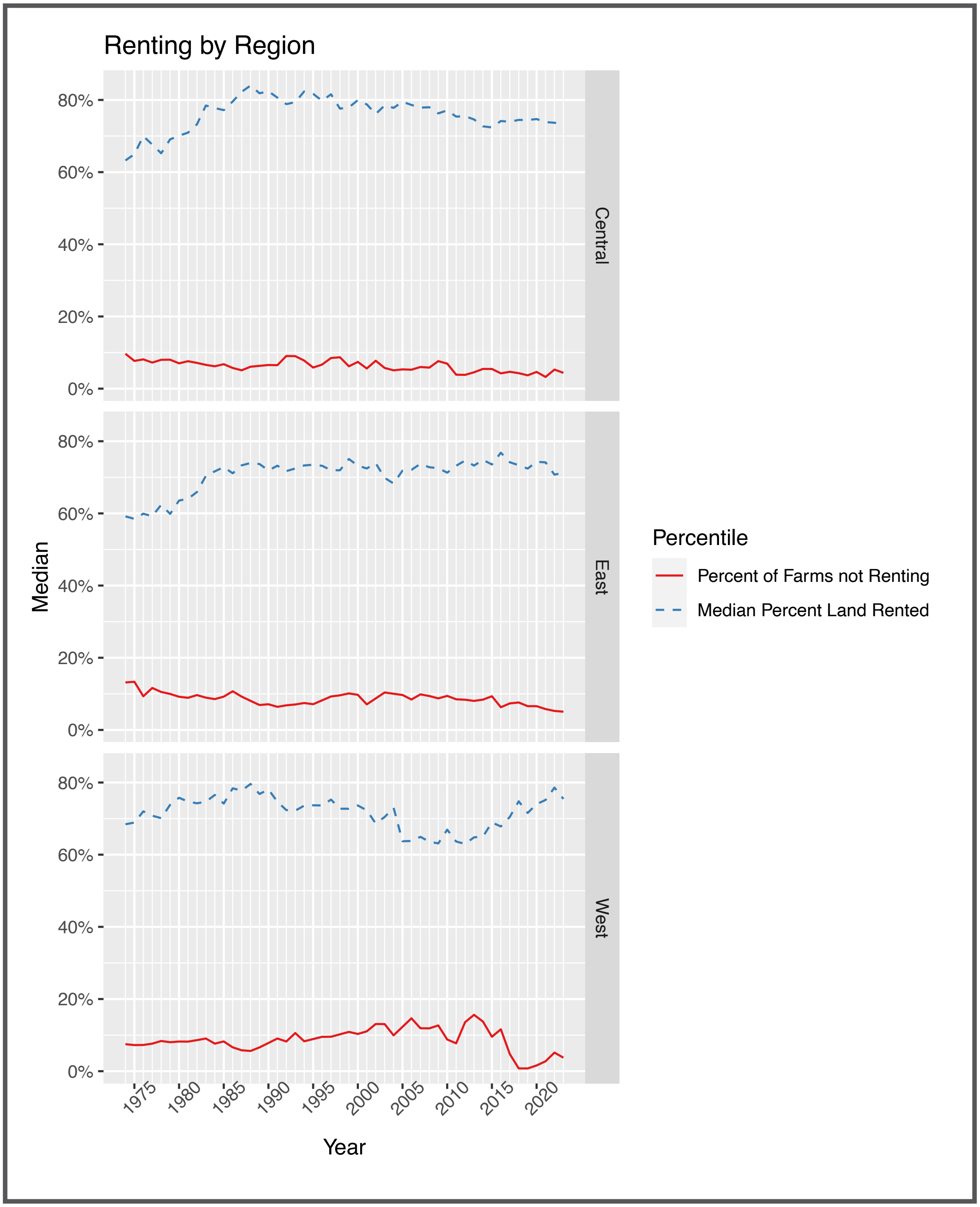

Figure 1. Median percent of land rented and percent of farms not renting by region

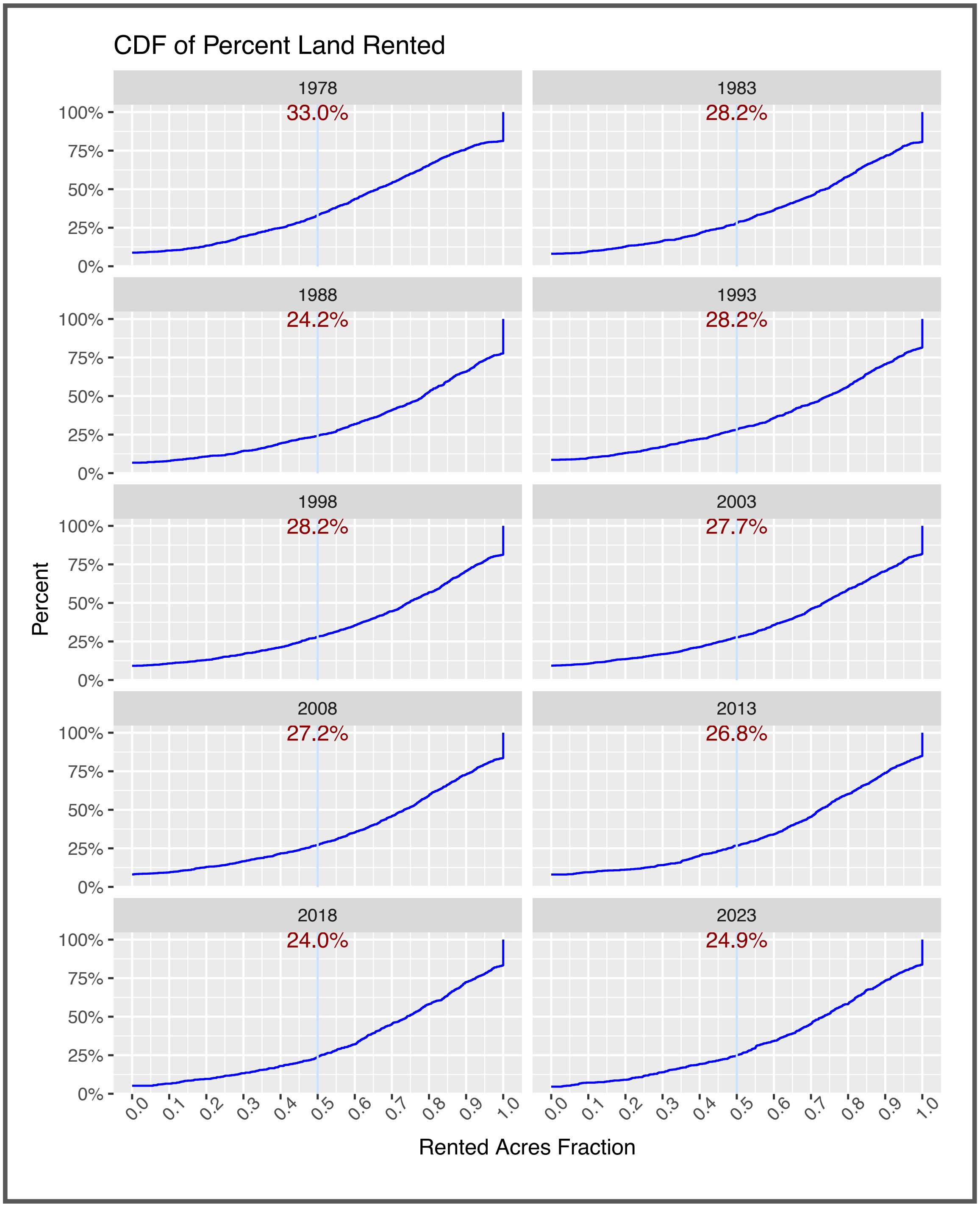

Figure 2. CDF of percent land rented at five-year intervals

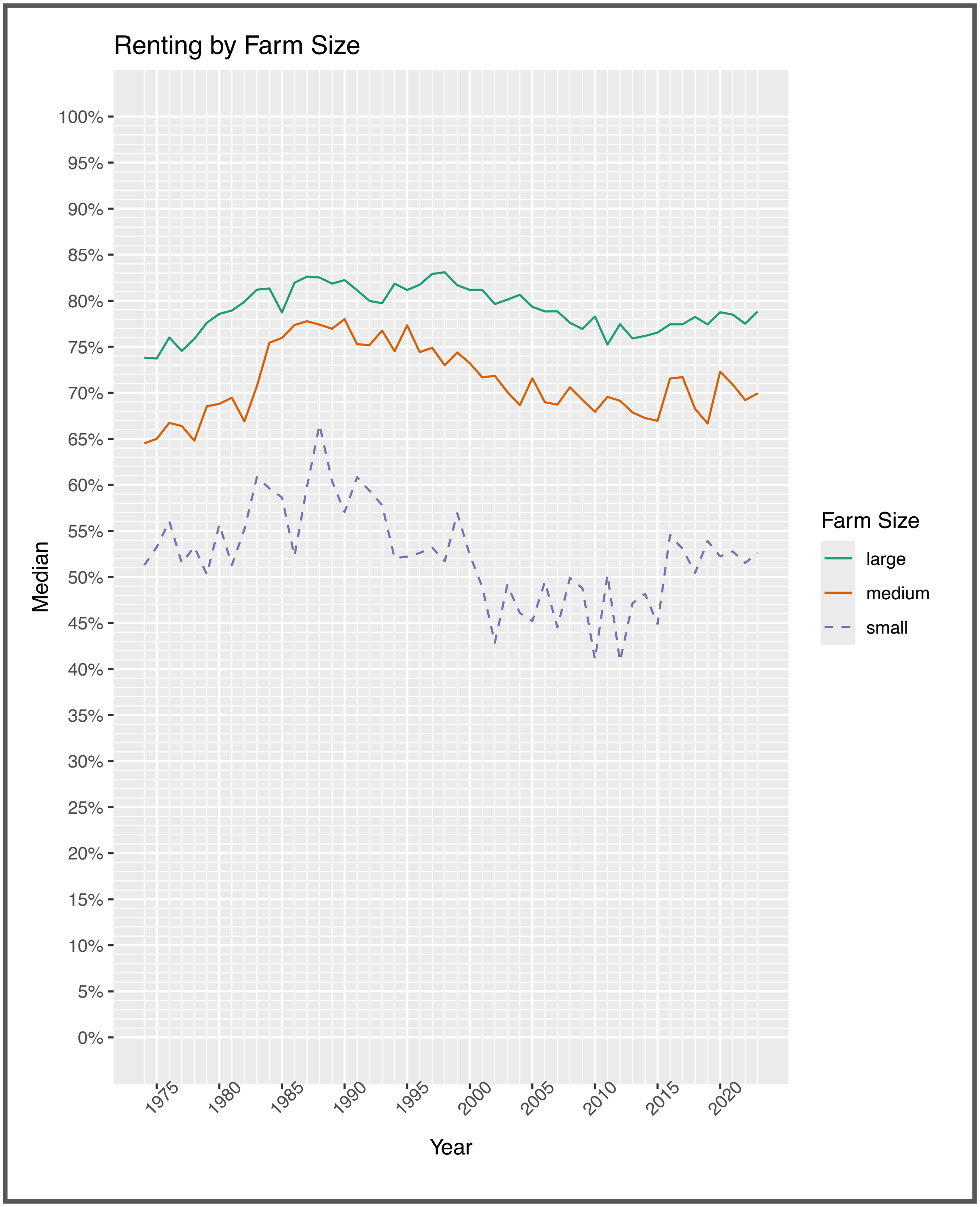

Figure 3. Median percent of farmland rented by farm size

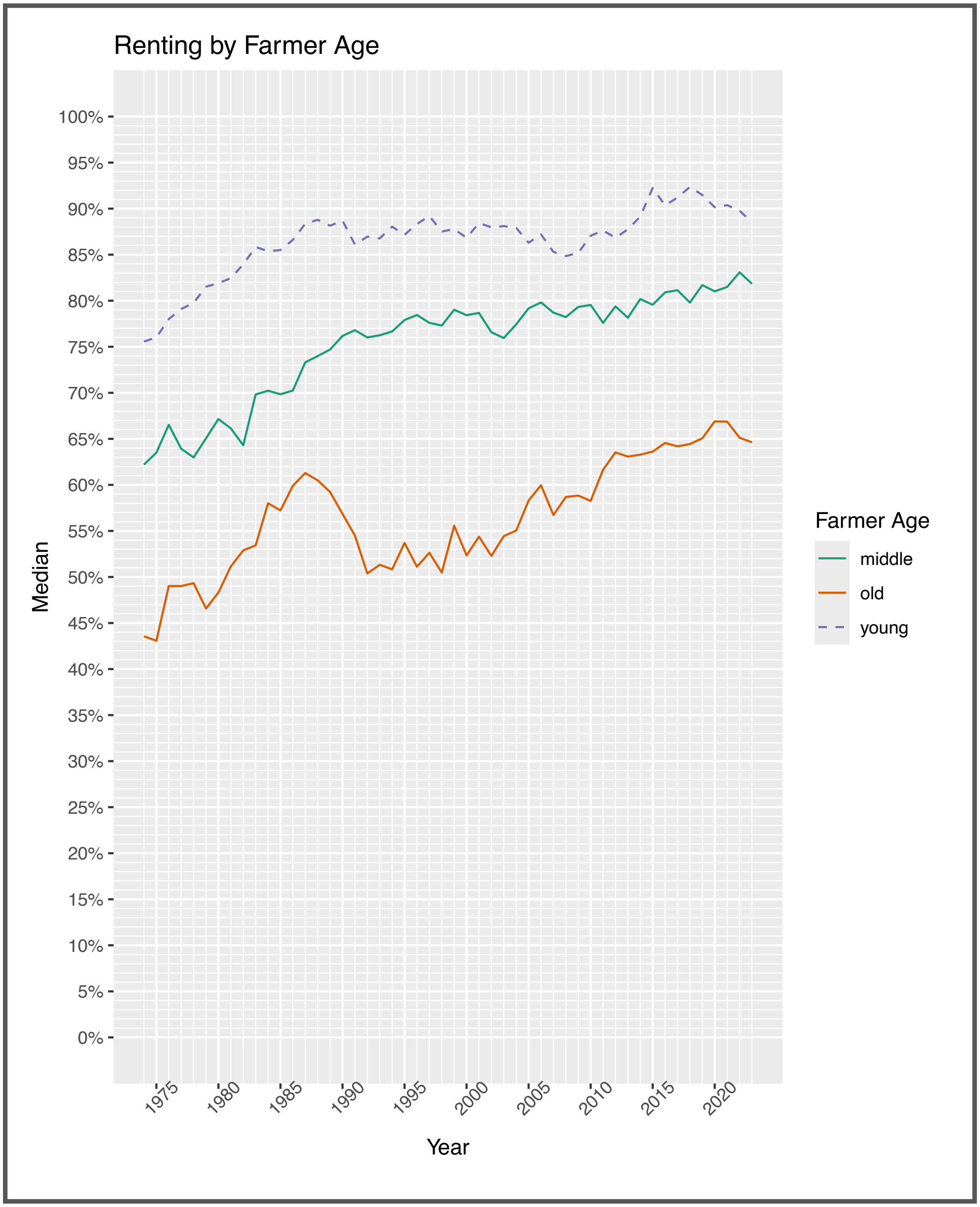

Figure 4. Median percent of farmland rented by principal operator age

Are Indebted Family Farms at Higher Risk of Financial Stress?

By Sarah Atkinson

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The views expressed in this paper are the author's and not necessarily the views of USDA.

Abstract

Four separate measures of farm financial stress were constructed using financial ratios and Farm Financial Standards Council benchmark levels. The percentage of farms meeting each measure was estimated using Agricultural Management Survey data for the years 2013–2021 and compared across farms categorized by level and type of farm debt for full-time family farms, survey year, commodity specialization, and farm size. Results indicate that, on average, indebted full-time family farms (7.4%), particularly those with an FSA guaranteed farm loan (9.2%), were at higher risk of financial stress compared to full-time family farms without farm debt, part-time family farms, and nonfamily farms.

INTRODUCTION

Agricultural producers rely heavily on local and small community banks to provide agricultural credit. Small community banks, often located in and serving rural counties, constituted 70% of agricultural lending from commercial banks as of 2022 (Gaffney, 2024; NAFCU, 2022). Historically, small community banks have been the largest provider of USDA Farm Service Agency (FSA) guaranteed loans, comprising 60% of all FSA guaranteed loans between 2005 and 2007 (Dodson, 2014). By enabling community banks to provide credit to agricultural producers, who otherwise cannot access commercial credit, FSA guaranteed loans contribute to the overall vitality of the agricultural sector and local economies. The increased financial stress levels facing producers could negatively impact loan portfolios and community banks' financial health, creating ripples throughout the local economy and negatively impacting markets for agricultural inputs, including machinery and farmland.

Financial stress can be defined as the inability of a borrower to meet debt service payments and can lead to the loss of credit, bankruptcy, and other serious long-term consequences if not alleviated. Financial stress tends to increase with higher debt levels, rising interest rates, and falling farm incomes (Briggeman, 2010), and with recent declines in net cash farm income and continued above-average interest rates, many farmers could be at risk of financial stress in 2025 (USDA ERS b, 2024; Kaufmann and Kreitman, 2024).

This study proposes four related measures of financial stress that are constructed by using combinations of financial ratios and the recommended benchmark levels provided by the Farm Financial Councils Standard (FFSC, 2020). We can use these measurements to estimate the average percentage of farms at high risk of financial stress between 2013–2021 with data from the Agricultural Resource Management Survey (ARMS). Estimates are compared across three groupings of debt types: farms with a USDA FSA guaranteed loan (FSA guaranteed loan farms), family farms with debt other than an FSA guaranteed loan (indebted family farms), and all farms. The first two groups are mutually exclusive as all farms encompasses all farms in the ARMS, including those in the first two segments.

The results show that farms with any debt are at greater risk of financial stress compared to all farms (9.2% for FSA guaranteed loan farms, 7.3% for indebted family farms, and 2.4% for all farms). Variation occurs across years, farm size, and farm commodity specialization, with small farms having the highest share at risk of financial stress (8.0%), followed by large farms (7.0%), then mid-sized farms (6.0%). Indebted family farms focused on the poultry, rice/cotton/tobacco/peanut, and hog sectors have a higher share of those at risk of financial stress compared to beef cattle or dairy farms.

FARM-LEVEL FINANCIAL DATA

The USDA FSA operates different farm loan programs to meet the needs of farmers, and one of these is the guaranteed loan program. Under the guaranteed loan program, FSA provides a guarantee of up to 95% against borrower default on qualifying loans made through approved lenders (USDA FSA, 2024). These loans are obligated and serviced by the lender; the borrower must meet certain criteria, including operating a small-sized family farm, not being delinquent on any federal debt or having received prior debt forgiveness, having good credit and the capacity to service the loan, and being unable to obtain commercial credit at reasonable rates and terms without the FSA guarantee. For borrowers unable to obtain commercial credit, FSA guaranteed loans are a needed source of credit and can serve as an entry into a credit relationship with the bank, forging a pathway to future borrowing opportunities. These loans enable banks to provide credit to borrowers otherwise deemed too risky and expand their lending base.

Since guaranteed loans are originated and serviced by outside lenders, FSA maintains limited borrower-level financial data on guaranteed borrowers, hence, many of the measures needed to estimate financial ratios are not available in the FSA administrative loan data. These instead were obtained from ARMS.

ARMS is USDA's primary source of information on the financial condition and production practices of American farms and the economic well-being of farm households (USDA ERS, 2024). It is an annual stratified random sample of farm operators across different farm sizes and production types within 48 U.S. states. Farms are stratified by region, farm size, and commodity specialization.

Within the FSA farm loan administrative data, each borrower is given a unique time-independent identifier called a core customer ID (CCID). Within ARMS, each respondent is given a unique time-independent identifier called the POID. Using these identifiers and ARMS survey data for the years 2013–2021, FSA guaranteed loan borrowers were identified in the survey data by survey year. This allowed the construction of a dataset of ARMS observations representing 162,889 farm operations over a nine-year period with indicators for those operations that had an outstanding FSA guaranteed loan by year.

FINANCIAL RATIOS AND BENCHMARKS

The Farm Financial Standards Council (FFSC) establishes standard definitions and methodologies for calculating financial measurements and ratios for agricultural producers (FFSC, 2020). These are then used to create and report national- and sector-level measures of farm economic performance and are utilized by individual lenders, suppliers, and others when evaluating the credit worthiness of borrowers (Key et al., 2019).

Three categories of financial ratios are typically used when evaluating credit worthiness: repayment capacity, liquidity, and solvency. Repayment capacity measures the ability of a business to provide for living expenses while also meeting business expenses and debt payments including, long-term replacement of capacity and future investment. Liquidity measures availability of cash and assets to meet short-term obligations. Finally, solvency examines the relationship between assets and liabilities (claims on these assets). Each of these measures provides useful information about the financial health of the borrower when compared against a valid reference point.

The FFSC provides comparison ranges, referred to as benchmarks, that can be used by individual farm operators to measure and track their performance over time against farms of similar size and production type. These benchmarks classify farms into one of three categories of relative risk, based on the value of their financial ratio in comparison to the benchmark value: low, moderate, or high. Multiple benchmark values in the high-risk category may be an indicator of underlying issues and could lead to future financial stress.

MEASURES OF FARM FINANCIAL STRESS

The initial measure of financial stress is the same as used in Key et al. (2019) and referred to here as *BASELINE*. This measure ranks farms as financially stressed if they fall below the FFSC critical value for two common solvency and repayment capacity measures, the Debt to Asset (DTA) Ratio and the Term Debt Coverage Ratio (TDCR). The DTA, calculated as total debts divided by total assets, measures the operation's ability to cover financial liabilities through the sale of financial assets. The TDCR is calculated as net farm income plus interest payments and depreciation less household income expenses divided by interest expenses and payments on term debt and capital leases. It measures the operation's ability to pay short-term debts out of current earnings while still meeting living expenses and replacing capital. An operation is considered to meet the *BASELINE* criteria for financial stress if both its DTA is greater than 0.55 and its TDCR is less than 1.0.

Measures to account for short-term liquidity, the current ratio (CR) and the working capital to expense (WCTE) ratio, are added consecutively to create two additional metrics for financial stress: *STRESS1* and *STRESS2*. CR is calculated as current assets divided by current liabilities, and it measures the ability of the farm to cover short-term liabilities as they come due using liquid assets. WCTE is calculated as current assets less current debts divided by total expenses, and it measures the farm operation's ability to pay short-term expenses. An operation meets the financial stress criteria for *STRESS1* if it meets the *BASELINE* criteria and its CR is less than 1.0. It meets the financial stress criteria for *STRESS2* if it meets the *BASELINE* criteria and has a WCTE less than 0.20.

The fourth measure of financial stress, *STRESS3,* is formed by considering both CR and the debt payment to income ratio (DPIR). DPIR is another measure of repayment capacity and is calculated as annual interest payments and capital leases divided by annual net farm income. The operation meets the financial stress criteria for *STRESS3* if it meets the *BASELINE* criteria and either has CR less than 1.0 or DPIR above 0.50. These measurement criteria are summarized in Table 1.

COMPARING FINANCIAL STRESS LEVELS

The total percentage of farms in the sample meeting each financial stress measure was compared across different groupings, including commodity specialization. Commodity specialization was constructed using the ARMS variable FARMTYPE by grouping farms into production categories based on the crop or livestock category representing 50% or more of the farm's revenue that year. ARMS expansion weights were used, as well as the "delete a group" jackknife variance estimator to adjust standard errors for complex survey sample methods.

In addition to commodity specialization, farms are classified based on presence and type of debt. FSA guaranteed loan farms include farms where the primary operator had an outstanding FSA guaranteed farm loan as of December of the given survey year. This category is inherently limited to family farms, since that is an FSA program requirement (USDA FSA, 2024). Indebted family farms includes family farms[1] that reported having interest expenses or debt payments other than an FSA guaranteed farm loan[2] in the 12 months preceding December of the survey year. Finally, all farms is inclusive of the first two types as well as family farms with either primary occupation as farming and no farm debt; farms with retired or part-time operators with or without farm debt; and non-family farms with or without farm debt. The share of farms by outstanding debt type, on average, between 2013–2021 is shown in Figure 1.

Finally, the percentage of farms at risk of financial stress using measure *STRESS3* was compared across survey year, farm size, and commodity specialization. To test if these results were significantly different across these different groupings, a logistic regression of the probability of *STRESS3* as a function of farm size, commodity specialization, survey year, and FSA guaranteed borrower was estimated by using PROC SURVEY REG and applying ARMS expansion weights and jackknife standard errors. The coefficient on the indicator for FSA guaranteed borrower was positive and statistically significant at the 95% confidence level, indicating that having an FSA guaranteed loan is associated with a higher probability of being at risk of financial stress. The regression results are available upon request.

RESULTS

Table 2 shows the average percent of farms at high risk of financial stress between 2013–2021 by the financial stress measures for each debt type.

Between 2013–2021, on average, between 2.1% and 2.4% of all farms were classified as at high risk of financial stress depending on the measure (Table 2). A larger share of indebted family farms (between 6.6% and 7.4%) met the criteria for high risk of financial stress compared to the average farm population. An even larger share (between 7.7% and 9.2%) of FSA guaranteed loan farms met a financial risk criterion. Table 3 estimates the share of farms at high risk by commodity for each measure of financial stress.

As seen in Figure 2, the exact percent of farms at risk of financial stress varies by year. On average between 2013–2021, the percent of farms in financial stress (using the *STRESS3* criterion) peaked in 2015 at 8.9% of indebted family farms, 11.4% of farms with an FSA guaranteed loan, and 3.0% of all farms (Figure 2). This fell to 6.5% of indebted family farms, 6.1% of farms with an FSA guaranteed loan, and 2.4% of all farms in 2016. The percentage proceeded to rise the next years until peaking at 8.9% of indebted family farms, 11.4% of farms with an FSA guaranteed loan, and 3.0% of all farms in 2019, before falling again to 7.1% of indebted family farms, 7.0% of farms with an FSA guaranteed loan, and 1.9% of all farms in 2021 (Figure 2).

A great deal of the rise in financial stress from 2016 through 2019 and the subsequent fall through 2021 can be tied to changes in annual farm income levels. Periods of high income can reduce the risk of financial stress. Using FINBIN data from the Center of Farm Management in Minnesota, Langemeier (2022) found that increases in net farm income in 2020 and 2021 led to improvement in CRs and WCET ratio and resulted in liquidity at levels not seen since 2012. Improvement in these ratios will lead to reductions in the percentage of farms at risk of financial stress.

Alternatively, periods of low farm income can exacerbate the risk of financial stress. Using FINBIN data, Langemeier (2022) found that CRs and working capital to gross revenue ratios of farms fell from 0.43 in 2012 to 0.256 in 2019, and the working capital to gross revenues ratios of farms fell from 2.65 in 2012 to 1.58 in 2019. The impact of falling incomes on farms can be larger on those starting in weaker positions. Using FINBIN data, Berg (2022) similarly found that between 2015–2019, during a period of weakness in the farm economy, those in the lowest 20% of profitability based on net farm income saw working capital erode to less than $25 per acre and liquidity reach dangerously low levels.

This can have severe consequences on short- and long-term farm profitability and survival. As liquidity erodes, farmers are often forced to restructure debt or sell assets to cover short-term needs and may face little flexibility in the timing of input purchases or crop sales. They may find it difficult to replace machinery, rent or purchase land, or take other measures to expand operations (Langemeier, 2022).

Table 4 estimates the percent of farms at high risk of financial stress under measure *STRESS3* and across different farm size categories. Similar to the prior results, the percentage of indebted family farms at high risk of financial stress (and in particular, those with an FSA guaranteed loan) is larger than that of the general farm population. The percentages vary though by farm size. For indebted family farms and farms with an FSA guaranteed loan, small farms (7.7% and 9.5% of farms) followed by large farms (7.0% and 9.4% of farms) have the largest percentage of farms at risk of financial stress compared to medium-size farms (6.2% and 8.4%). For the farm population in aggregate, the relationship between financial stress and farm size changes, with large farms having the largest percent of farms at high risk of financial stress (5.6%) followed by medium farms (3.8%) compared to only 2.1% of small-sized farms.

Figure 3 presents the percent of farms at high risk of financial stress under measure *STRESS3* and across different farm commodity types. As seen in Table 3 and Figure 3, the percentage of farms at risk of financial stress varies widely by commodity. Poultry farms had the largest percent of indebted family farms and guaranteed farms at high risk of financial stress (13.9% and 18.3%), followed by rice, cotton, tobacco, and peanut farms (9.7% and 12.9%). The risk of financial stress was also relatively high for indebted hog family farms (9.2%) and specialty crop farms with an FSA guaranteed loan (8.6%). Key et al. (2019) also found that large-scale poultry and hog producers had the highest levels of financial stress and credits this largely due to large investments in specialized facilities required by producers leading to higher degrees of leverage.

Of indebted family farms, dairy and beef cattle had the lowest percentage of farms at high risk of financial stress (5.4% and 6.0%). The lowest percentage of farms with an FSA guaranteed loan at risk of financial stress was concentrated in general crop and livestock farming (5.1%), followed by dairy and hog production

(7.0% and 7.2%). General crop and livestock farms include farms where no single crop or livestock farm comprises at least 50% of total sales that year. This diversity across crop types may insulate some farms from financial stress when fluctuations in farm prices in one category are offset by those in other categories.

Consistent with the results above, a greater percentage of small farms with debt, and farms with an FSA guaranteed loan more so, are at risk of financial stress compared to the overall farm population. Overall, the variation between stress levels by commodity appears greater for indebted family farms and farms with a guaranteed loan compared to all farms.

IMPLICATIONS

The difference in the percentage of farms facing financial stress using the average of all farms and when only indebted full-time family farms were selected highlights a significant problem that can arise when producers, lenders, or program administrators seek to use benchmark data based at the aggregate level to either estimate expected levels or compare current levels of financial stress. By taking summary statistics over aggregate data, one does not account for the key distributional characteristics that are correlated with differences in financial metric measurements among different subpopulations. Ignoring these differences, the resulting measures can grossly under- or overestimate the true measures of the subpopulation. Two of these key distributional characteristics to account for when estimating the risk of financial stress are debt levels and access to off-farm income.

A high percentage of producers have little or no debt. As a result, aggregate measures provide little evidence of the proportion of farms with high levels of leverage (Ellinger et al., 2016). Given that the farms with high debt to asset ratios are particularly vulnerable to financial stress overall and in particular during times of rising interest rates and/or falling incomes (Kuhns and Patrick, 2018; Langemeier and Boehlje, 2024), using aggregate data and financial measures incorporating debt to asset ratios may understate the full level of financial stress.

Additionally, using aggregate data does not take into account the share of farms with access to off-farm debt. Roughly 90% of small family farms are operated by retired or part-time farmers, and 84% of farm households earn the majority of their farm income from off-farm sources. This off-farm income is used to cover a portion of farm expenses and is especially true of those households with low sales (GCFI < $150,000 annually) and retirement farms. These farm operations often have little or no debt and hence are less impacted by swings in farm economy in comparison to small and midsized family farms. In contrast, family farms often rely on farm income to cover family expenses. This lack of cushion to guard against fluctuating farm income levels makes them subject to greater vulnerability and production risk and may lead to higher levels of financial stress (Langemeier and Boehlje, 2024).

Additionally, large family farms often have higher debt to asset ratios and more variable net farm income compared to non-family farms. They are more vulnerable to financial stress due to these higher levels of debt, having less formalized management and greater reliance on family labor compared to non-family farms, which often have better access to capital and diversified income sources and may employ more robust risk management strategies.

In looking at the aggregate measure of financial stress for all farms, very few farms appear to be at risk of financial stress. This misses the greater levels of indebted family farms that may be at risk, though, especially when farm size and commodity types are taken into account. Not taking this into account when formulating policy or when evaluating lending portfolio health can create a false sense of security and prevent implementing measures to tackle these problems early.

Additionally, when evaluated against all farms, FSA guaranteed loan borrowers appear to have a significantly higher risk of financial stress, but when compared against a similar subpopulation, i.e., indebted family farms, a large portion of this difference disappears. Screening for these differences when using aggregate data will result in more accurate measures of risk and allow the crafting of appropriate responses. In addition, using datasets that focus on full-time borrowers, such as FINBIN, or that cover limited geographics and production types to calculate the above metrics can also provide useful benchmark comparisons.

CONCLUSIONS

This study compares the percentage of farms at risk of financial stress between 2013–2021 using ARMS data and four different measures of financial stress derived from financial ratios and FFSC critical benchmark levels. Measures of financial stress are compared across year, commodity, and farm size, and comparisons are made between farms with FSA guaranteed loans, indebted family farms without FSA guaranteed loans, and all farms. On average, between 2013–2021, a larger percent of indebted family farms (between 6.6% and 7.4%) and farms with an FSA guaranteed loan (between 7.7% and 9.2%) were at risk of financial stress compared to all U.S. farms (between 2.1% and 2.4%). On average, hog, poultry, and rice/tobacco/cotton/peanut farms had the largest percentage of farms at risk of financial stress, as did small-sized family farms. The variation by levels of debt and off-farm income (indebted family farms vs. all farms) and within farm size, year, and commodity illustrates the importance of adjusting for these categories when seeking to determine farms most likely to experience financial stress. When crafting policies to address expected levels of financial stress, different policies may be required when addressing the issues faced by family farms with full-time operators and government programs that heavily serve this population, such as FSA farm loan programs, compared to policies aimed at and programs serving the overall farm population.

These measures and results are useful for agricultural researchers, producers, and particularly for program administrators and lenders specializing in agricultural loans. The proposed measures are simple, use readily available data, are easy to explain to lenders and program staff, and provide consistent but informative results. By applying these metrics to agricultural loans and lending programs, lenders and program administrators can ascertain the overall health of their loan portfolio and identify those borrowers most likely to experience repayment issues in the future. Once identified, proper intervention can be designed to help mitigate risks among identified individual borrowers or groups of borrowers. Proactively evaluating borrower financial stress levels is essential in times of falling agricultural incomes and high interest rates and is a key element of a robust risk management strategy to ensure that banks, rural lending institutions, and government credit programs continue to support strong and vibrant rural communities regardless of external economic conditions.

FOOTNOTES

1 A family farm is defined as any farm where the majority of the business is owned and operated by the principal operator and individuals related to the principal operator.While the ARMS classification for family farms includes those with an occupation other than farming (either retired or part-time), in this analysis, indebted family farms included only those farms where the operator's primary occupation was farming. This means that the operator spent at least 50% of his employment hours on farm work.

2 FSA farm loans are provided through two primary programs, direct and guaranteed loans. Farms where the operator had an outstanding balance on a direct loan only are included in indebted family farms.

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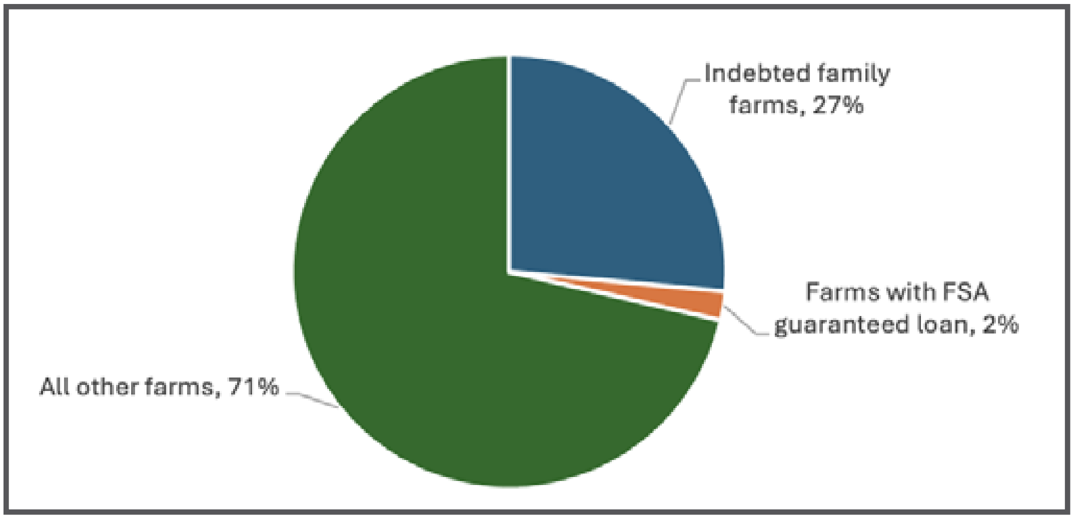


Figure 1. Average percent of all farms by debt type, 2013–2021*

*Indebted family farms are those where the majority of the business is owned and operated by family members (family farms) where the operator's primary occupation is farming, and that answered yes to the survey question, *Did the farm have interest expense or any other debt payments in the calendar year* (indebted), excluding those with FSA guaranteed loan debt. Farms with FSA guaranteed loans had an outstanding balance on an FSA guaranteed loan as of December of the given survey year. All other farms included family farms where farming was the primary occupation without debt, retirement farms, part-time farms, and non-family farms. ARMS expansion weights were applied. Source: ARMS data 2013–2021.

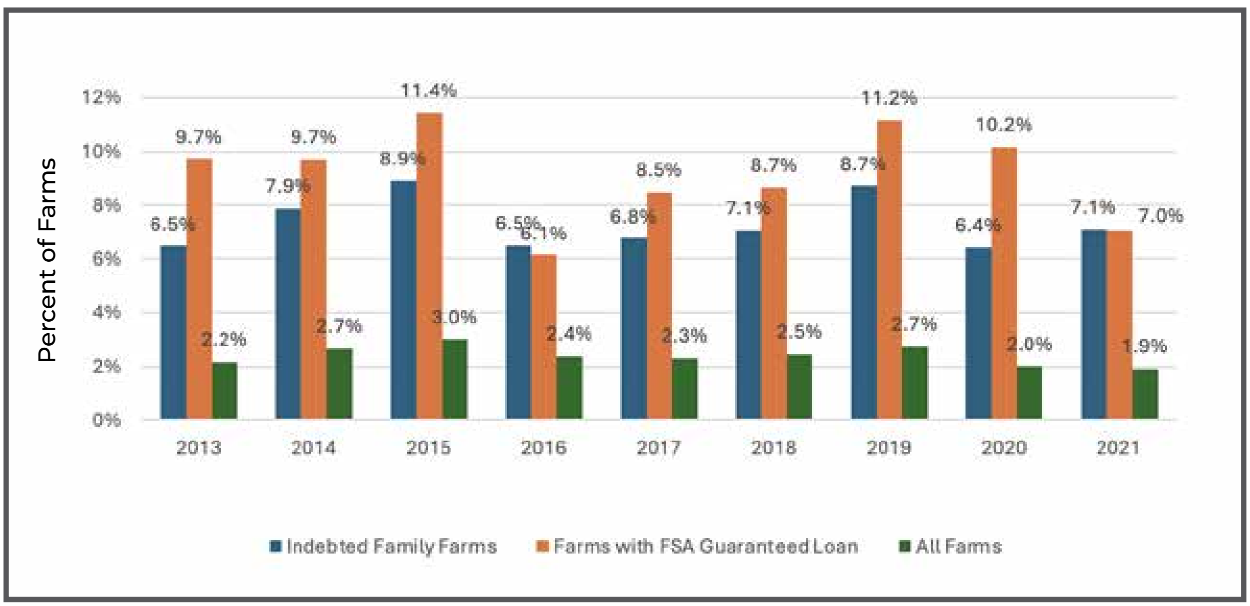


Figure 2. Average percent of farms at risk of financial stress by debt type and year, 2013–2021 using the STRESS3 criterion*

*Farms are categorized as at risk of financial stress if DTA > 0.55 and TDCR < 1.0 and either CR <1.0 or DPIR > 0.50. See notes Figure 1. Source: ARMS data 2013–2021.

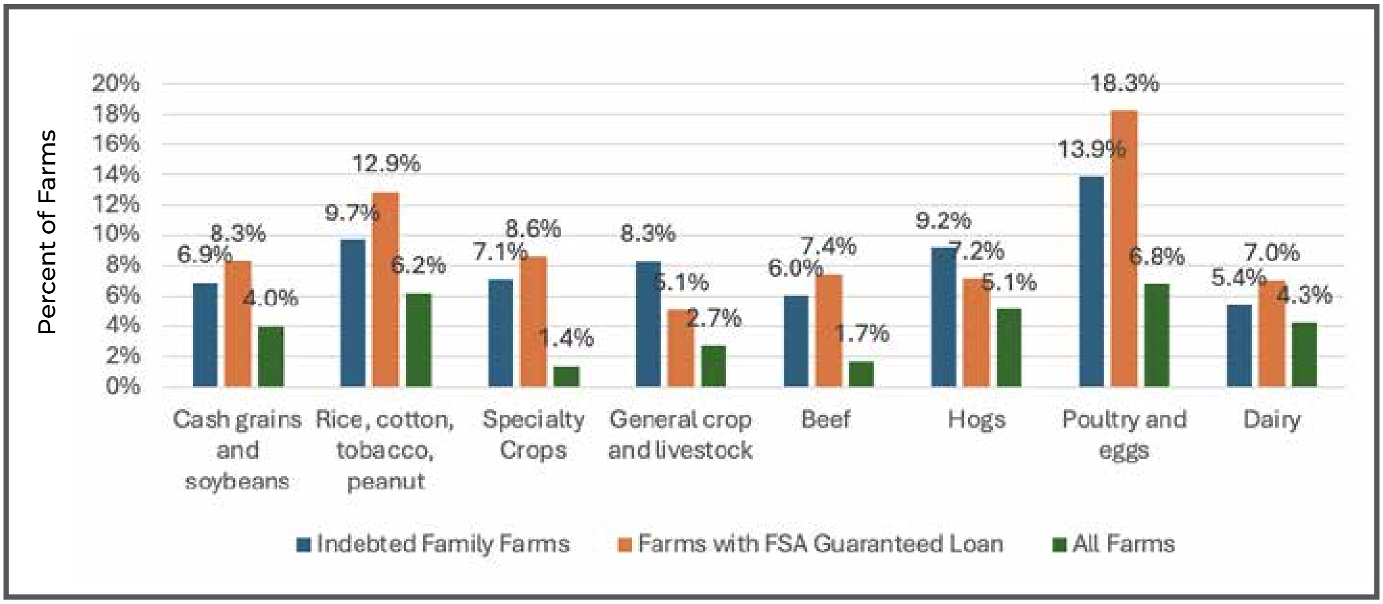


Figure 3. Average percent of farms at risk of financial stress by commodity specialization and debt type, 2013–2021 using the STRESS3 criterion*

*Farms are categorized as at risk of financial stress if DTA > 0.55 and TDCR < 1.0 and either CR <1.0 or DPIR> 0.50. Commodity is based on the commodity group that comprises 50% or more of the farm's sales that year. Cash grains include barley, corn, sorghum, wheat and oats. Specialty crops include fruit or dried fruits, tree nuts, vegetables, beans, and horticulture nursery crops. General crop and livestock include those crop and livestock categories not listed specifically in another category or farms in which the total produced no single category is greater or equal to 50% of the total farm's sales that year. See notes Figure 1. Source: ARMS data 2013–2021.

Table 1. Measures for Risk of Financial Stress*

Name	**Criteria**
Baseline	DTA > 0.55 and TDCR < 1.0
Stress1	Baseline and CR <1.0
Stress2	Baseline and WCTE <0.20
Stress3	Baseline and either CR < 1.0 or DPIR > 0.50

*DTA = debt to asset ratio, TDCR = term debt coverage ratio, CR = current ratio, DPIR = debt payment to income ratio, WCTE = working capital to expense ratio.

Table 2. Average Percent of Farms at Risk of Financial Stress by Financial Stress Measure and Debt Type, 2013–2021*

	BASELINE DTA > 0.55 and TDCR < 1.0	***STRESS1*** Baseline and CR <1.0	***STRESS2*** Baseline and WCTE < 0.2	***STRESS3*** Baseline and either CR < 1.0 or DPIR > 0.5
FSA Guaranteed Loan Farms	9.2	7.7	8.8	9.2
Indebted Family Farms	7.4	6.6	7.1	7.3
All Farms	2.4	2.1	2.3	2.4

*Source: ARMS data 2013–2021.

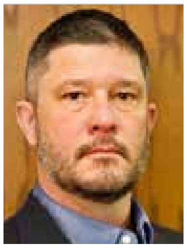
Table 3. Average Percent of All Farms at Risk of Financial Stress by Financial Stress Measure and Commodity Specialization, 2013–2021*				
	BASELINE **DTA > 0.55 and TDCR < 1.0**	***STRESS1*** **Baseline and CR < 1.0**	***STRESS2*** **Baseline and WCTE < 0.2**	***STRESS3*** **Baseline and either CR < 1.0 or DPIR > 0.5**
Cash grains and soybeans	4.1	3.1	3.9	4.0
Rice/cotton/tobacco/peanut	6.3	4.1	6.1	6.2
Specialty crops	2.7	2.3	2.7	2.7
General crop and livestock	1.4	1.2	1.4	1.4
Beef	1.7	1.6	1.6	1.7
Hogs	5.1	4.1	4.9	5.1
Poultry and eggs	6.8	6.0	6.6	6.8
Dairy	4.3	3.7	4.1	4.3

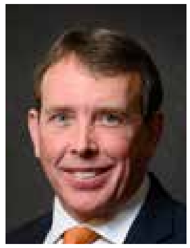
* Commodity is based on the commodity group that comprises 50% or more of the farm's sales that year. Cash grains include barley, corn, sorghum, wheat, and oats. Specialty crops include fruit or dried fruits, tree nuts, vegetables, beans, and horticulture nursery crops. General crop and livestock include those categories not listed specifically in another category or farms in which the total produced no single category is greater or equal to 50% of the total farm's sales that year. Source: ARMS data 2013–2021.

Table 4. Average Percent of Farms at Risk of Financial Stress by Farm Size and Debt Type, 2013–2021*			
	Small	**Medium**	**Large**
FSA Guaranteed Loan Farms	9.5	8.4	9.4
Indebted Family Farms	7.7	6.2	7.0
All Farms	2.1	3.8	5.6

* Farms are categorized as at risk of financial stress if DTA > 0.55 and TDCR < 1.0 and either CR <1.0 or DPIR> 0.50. Farm size is based on annual Gross Cash Farm Income (GCFI). Small farms have GCFI less than $350,000, midsized farms have GCFI between $350,000 and $1 million, and large farms have GCFI greater than $1 million. Includes all farms. See notes Figure 1. Source: ARMS data 2013–2021.

Trends and Seasonality in Cattle Auction Data from the Southeast





By Matthew Fischer, Anastasia W. Thayer, and Nathan Smith

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Abstract

The Southeastern United States plays an important role in the beef cattle supply chain, featuring diverse cow-calf operators that supply an annual calf crop. Since 2010, periods of expansion and contraction have occurred, altering the number of cattle in the national herd, but within the Southeast, changes have also occurred to the number and size of operations and marketing strategy. In this research, we explore the volume and price of feeder steers, bulls, and heifers from 2010 to 2019 for auctions in North Carolina, South Carolina, and Georgia. Using data from 255,651 auction transactions, we show seasonal patterns in volume and prices and suggest changes to marketing.

INTRODUCTION

The beef cattle sector experiences periods of contraction and expansion, which alter the total number of cattle, supply and demand dynamics, and requires additional management to maintain producer profitability (McBride and Mathews, 2011; Griffith, Burdine, and Anderson, 2017). Depending on production limitations (forage base and weather events such as drought), the supply of feeder cattle can fluctuate considerably across regions in the United States and possibly within geographic regions. These factors contribute to a dynamic and challenging marketing environment for feeder cattle producers. At the same time, understanding seasonal patterns in local feeder cattle marketing can provide insight into supply and demand signals on a smaller scale.

Historically, the Southeast region has supported numerous, small-scale cow-calf operations and played an important role in the beef cattle supply chain, providing an annual calf crop (McBride and Mathews, 2011). In recent years, operations across the U.S. have become more specialized, with a higher proportion of cow-calf operations focusing solely on beef production, without diversifying into other commodities (Gillespie, Whitt, and Davis, 2023). Additionally, there has been a decline in the number of operations that retain animals for stocker operations. (Gillespie, Whitt, and Davis, 2023). Meanwhile, there was evidence suggesting a decline in the overall cattle herd, a reduction in the number of small operations, and a shift toward fewer, larger operations. (Gilespie, Whitt, Davis, 2023; O'Hara, 2023). These simultaneous changes to operations in the Southeast and broader national cattle markets create a challenging market for small-scale cow-calf operations.

As part of the movement toward more specialization, changes in marketing and production strategies have been observed. In the Southeast in particular, an increased number of cattle have been marketed through online platforms, with premiums for certified natural or other attributes observed (Burdine, Halich, and Lehmkuhler, 2014). At the same time, efforts to educate producers on the timing of calving and weaning cycles to take advantage of forage availability and profitability have been emphasized (Funston et al., 2016). These further complicate a producer's decisions regarding the timing of marketing and strategies used to sell calves and increase prices.

The purpose of this research is to document and explore trends and seasonal patterns in feeder cattle prices and transaction volume in the Southeast from 2010–2019 using data of individual sale transactions from the United States Department of Agriculture Agricultural Marketing Service. This period represents both times of contraction and expansion in the overall domestic cattle herd and focuses on three Southeastern states (North Carolina, South Carolina, and Georgia) to illustrate the seasonality of feeder calves in the Southeast. This subset region of the Southeast features a similar forage base and production characteristics and offers a large enough region for marketing analysis. Emphasis will be placed on observing the differences in price and volume for feeder steers, bulls, and heifers marketed through auctions during this period. Understanding expected seasonal price movements can provide producers with important information needed to make production and marketing adjustments to increase profitability.

BACKGROUND

Prior research has sought to understand feeder cattle price dynamics and determinants using auction data. This literature has used a variety of techniques, including econometric models, to assess how auction prices might change based on various attributes. These assessments have occurred periodically over time and market locations (Buccola, 1980; Schroeder et al., 1988; Martinez et al., 2021). This work can be used to aid producer decision-making by understanding which attributes command a higher price, information that can then be used by a producer to inform management decisions.

A few specific findings relevant to producers making decisions have analyzed price differences for specific cattle attributes or premiums paid for management decisions. For example, findings from analysis of auction data have shown price differentials based on breeds (McCabe et al., 2019). Other research has investigated price differentials for feeder cattle steers versus bulls, which could inform castration decisions before marketing (Martinez, 2020), with more specific details on lots and the premium associated with additional veterinary care or management, such as achieving third-party certification (Williams et al., 2012).

In addition to specific attributes about the animals, other prior research has focused on understanding the timing and seasonality of marketing and its influence on price. Many of the aforementioned studies and others, such as Jones et al. (2023), researched auction prices and have included a way to capture differences in prices across months or seasons. Given the dynamic nature of specific markets and the overall cattle cycle timing, the marketing of cattle to specific months or at a given time to command a higher price can be complicated, and models to capture this decision can be complex (Wang et al., 2001; Tester et al., 2020). Yet, other work has shown opportunities for producers to take advantage of profitable opportunities related to stocker enterprises (Key et al., 2023) or the timing of sale (Seamon et al., 2019).

We seek to add to this literature by focusing on an understudied region for an extended time horizon. The analysis here is summary in nature but focuses on identifying and translating specific trends and patterns for use in decision-making.

DATA

Feeder cattle auction price data was gathered from the United States Department of Agriculture Agricultural Marketing Service for a subset of Southeastern states from 2010–2019. Data on individual transactions from 41 auction reports was compiled from North Carolina (10 reports), South Carolina (8 reports), and Georgia (23 reports). In total, 255,651 transactions were analyzed, covering the sale of 2,132,018 feeder cattle. For each transaction, the following information was available: animal type (steer, bull, heifer), number of animals sold, weight, and average price.

This study focuses on three Southeastern states: North Carolina, South Carolina, and Georgia. The states were selected based on similarity in terms climate conditions, and all have a coastal plain to the East and are boarder to the West by the Appalachian

Mountains. Despite only including three states, the beef cattle industry represented by inventory numbers is an important part of that state's agricultural economy. In 2024, the total cow inventory across these states was estimated to be 352,000 (NC), 148,000 (SC), and 459,000 (GA) (USDA-AMS, 2023). The 2023 January 1 calf inventory for Georgia, South Carolina, and North Carolina was 360,000, 133,000, and 490,000, respectively (USDA-NASS, 2023). The three states total calf crop in 2023 was 983,000 calves.

Despite similarities in terms of the states selected for analysis, different geographic regions occur in each state. For this reason and to simplify analysis, two regions (East and West) were created; Figure 1 shows the geographic dispersion of reporting locations. The Eastern region, denoted with red stars, corresponds to the coastal region, and the Western region, denoted by black stars, corresponds to the Piedmont region. The separation occurs where the topographic inversion happens, the Atlantic Seaboard Fall-Line. The determination of the separate regions is based on a difference in climate, which also corresponds to forage base and topography. Specifically, the determination of the separate regions is based on the USDA plant hardiness zones (USDA-ARS, 2023). Most of the Eastern zone is in Zone 8b, which is limited in terms of available cool season perennial forages. As a result, these operations face additional costs of production to maintain feed during fall and winter months. The Western region falls into Zone 8a, which allows producers the option to use cool season perennials. The availability of cool season perennials provides an option for producers looking to lower input cost inputs for feeding.

For the purposes of analysis, animals were grouped based on weight and further delineated as steers, bulls, or heifers. Weight classes included in this analysis were 4-weight (400-499 lbs.), 5-weight (500-599 lbs.), and 6-weight (600-699 lbs.).

Finally, a total of 238 sales were removed due to a lack of information to be able to accurately place the observation into a region.

RESULTS

The aggregated cattle prices for the study period are shown in Figure 2, which highlights general changes in prices observed from 2010–2019. As expected, the general price movements follow national market prices during this time and are consistent across both the Western region (top) and Eastern region (bottom).

Both regions show a steep increase in market prices in 2014 and 2015. From 2010–2014, the national cattle herd was going through a period of contraction with the lowest national cattle herd numbers observed in 2014 (USDA-ERS, 2023). As expected, low supply led to high observed prices. A similar pricing premium for steers relative to bulls and heifers is observed for both regions in this contractionary period, with feeder steers in both regions commanding a higher price relative to feeder heifers. In the Western region, feeder bulls have a noticeable premium to heifers. Interestingly, the price spread for bulls and heifers in the Eastern region is relatively non-existent until 2014.

As prices increased beginning in 2013, the price spread collapsed for feeder bulls and heifers in the Western region. We observed that the price spread between feeder males and females tightened during periods of sharp price increases and decreases for the study period. During the 2014/2015 price peak, defined price spreads existed between females and males as expected. Post-2015, decreasing prices in both regions brought more consistent price spreads among steers, bulls, and heifers. An interesting point to note is the bull-heifer price spread in the East. Before 2014, bulls and heifers were valued relatively the same; post-2015, heifers are discounted relative to bulls.

During the study period, the national cattle herd numbers contracted (2010–2014) and expanded (2014–2018). The number of annual transactions occurring during the study period for feeder steers, bulls, and heifers is shown in Figure 3 for the Western region (top) and the Eastern region (bottom). Overall, the Western region recorded more transactions than the Eastern region. As expected, the number of transactions is relatively constant until a marked increase in the number of transactions occurs for most feeder cattle groups across both regions in 2014. This corresponds with the start of the expansionary period for the overall U.S. cattle herd. It is interesting to observe an increased number of transactions in 2013 in the Western region for all groups from 2013 compared to 2012.

Finally, starting in 2013, the number of bull transactions increased and grew rapidly in both regions. In the Western region, the number of bull transactions surpassed that of heifer transactions, a change that coincided with the increased market prices and persistent discounts for bulls relative to steers in both regions (see Figure 2). The number of bull transactions persisted through the end of the study period, and with it, a reduced number of steer transactions.

Price seasonality for gender weight classifications by region is illustrated in Figure 4. Lighter-weight cattle brought a premium price relative to heavier cattle and exhibited consistent seasonal patterns for all regions across feeder male and female groups. An annual slump in prices in July can be observed across both regions and for steers, bulls, and heifers. The magnitude of this decline varies and is stronger for male feeder cattle. Consistent seasonal patterns are also observed across regions for steers, bulls, and heifers. Beyond this comparison, seasonal price patterns vary across weight classes and among steers, bulls, and heifers.

For feeder steers, the month with the observed highest price varies by weight with different seasonal price patterns. In general, higher prices are observed in March, August, and November. For 400- to 499-lb steers, the highest price is recorded in March, both for the Western and Eastern regions. For 500- to 599-lb steers, the March and August prices are almost the same, whereas for the 600- to 699-lb steers, there is less seasonality, with higher prices from March through August.

For the lighter-weight steers, prices decline from March to July. From August to December, the prices remain flat, but in the Eastern region, November prices are at a premium to Western November prices. Compared to heavier-weight cattle, the 400- to 499-lb price seasonality shows the most volatility. Between March and July, the price spread between 400- to 499-lb cattle and heavier cattle narrows, but between August and July, the spread widens.

For heavier-weight steers, seasonal price variation is the least volatile for the three weight classes. The highest price month was August, with prices decreasing from August to October, which is the lowest-price month. The price spread between 500- to 599-lb and 600- to 699-lb steers in the Western region starts to narrow from January to July. After July, the price relationship remains stable, and the Eastern price remains consistent from January to June. In July, the price spread narrows, and this relationship remains so through the end of the year.

Feeder bull prices show similar price patterns as steers, but regional differences in magnitude and volatility of prices can be seen comparing Eastern and Western regions. Eastern feeder bulls are priced at a premium to Western feeder bulls at several time points in the year for both lighter-weight classes (400-499 lbs. and 500-599 lbs.) and heavier-weight classes (600-699 lbs.) While the general seasonal price pattern for bulls is similar to steers, there is a wider spread between lighter and heavier bulls compared to steers. Further, notable differences are visible in the highest-price and lowest-price month based on weight class and region.

Feeder heifer prices display less seasonality than male feeder cattle but mostly follow similar patterns. Feeder heifers in the 400- to 499-lb weight class in the Eastern region maintain higher prices compared to similar-weight cattle in the Western region. The high-price month for 400- to 499-lb heifers in both regions was May, whereas the high-price month for heavier weights (500-599 lbs. and 600-699 lbs.) was August. Across both regions and all weight classes, the low-price month was October.

Regional cattle transaction seasonality is shown in Figure 5 for steers, bulls, and heifers by weight class. Consistently, the Western region markets have more cattle than the Eastern region. As shown in Figure 3, more heifers are marketed across both regions than bulls or steers. In both regions, the seasonal movement is consistent with an increasing number of transactions from January to March, followed by a decreasing number of transactions for most weight classes and groups from March to July. For most weights of steers, bulls, and heifers, July brings fewer transactions compared to other summer months. In general, transaction volume increases in August but then decreases through the fall months and into December.

MANAGEMENT IMPLICATIONS AND CONCLUSIONS

As shown in Figures 2-5, the selected region of the Southeast displays consistent price patterns that follow the major price movements observed in the broader cattle market from 2010–2019. Further, the volume of transactions reflects similar patterns to expansion and contraction observed across the country. Interestingly, some regional differences can be seen in price trends and seasonal patterns of transactions.

First, as shown in Figure 2, during periods of sharp price movements (increases or decreases), expected price premiums or discounts disappear, and spreads between steers, bulls, and heifers are no longer present. Then, over this period, a clear change in the price spread between feeder males and females is observed for the Eastern region. In the expansion period from 2016–2018, a noticeable spread develops between feeder males and females that is not observed prior to 2014. This suggests that when sharp price movements occur, producers are willing to adjust management strategies and enter different marketing opportunities. An example strategy seems to include not castrating due to the market, which doesn't reflect the value in additional management.

Findings from Figure 3 suggest that, for the Eastern region, a change occurred during the study period in marketing strategy based on the changes in observed transaction volume from marketing steers to marketing bulls. While the source of this decision is unknown, in combination with pricing information for bulls versus steers, there could be an opportunity for understanding producer behavior and risk tolerance.

Finally, seasonality in prices across regions, weights, and groups of cattle, as shown in Figure 4, suggests potential opportunities for understanding local cattle prices to benefit producer decision-making and timing of marketing. This could include timing cattle marketing to take advantage of months with historically higher prices. For some producers, depending on location, consideration of weight at sale, or location of sale depends on the cattle marketed; however, this will likely be limited by forage availability and the seasonality of productivity across regions.

The study period of 2010–2019 represents a time of both expansion and contraction for the U.S. cattle herd. Drought across other cattle-growing regions, changes in cattle marketing strategies, and other factors caused substantial changes to prices and total cattle marketed during this time period. While all markets are connected, specific patterns and factors driving prices in the Southeast are not the same as in other parts of the country. Through this research into transaction-level data for feeder cattle auction sales, this research visualizes and provides a discussion of trends and seasonal patterns for the price and volume of transactions for feeder cattle in a subregion of the Southeast. Future research could focus on conducting this analysis on other subregions of the Southeast or even smaller marketing regions. Given recent changes to the industry due to COVID-19 and additional droughts, updated research from 2020–2024 could present additional findings relevant for Southeastern producers. Finally, load lot marketing and the use of third-party certification have been other strategies for producers to increase prices. Future research into the region could explore these programs in conjunction with historic auction markets.

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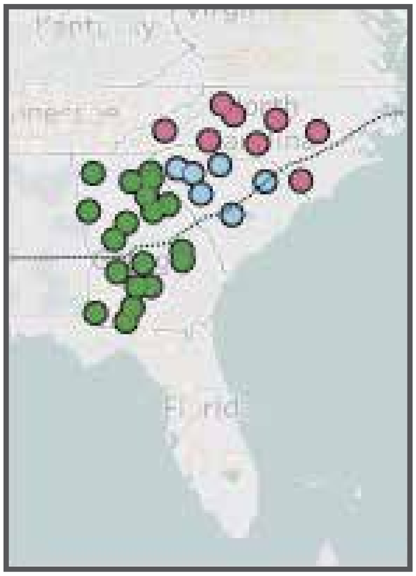


Figure 1. Auction market locations with markets in the Western and Eastern study regions

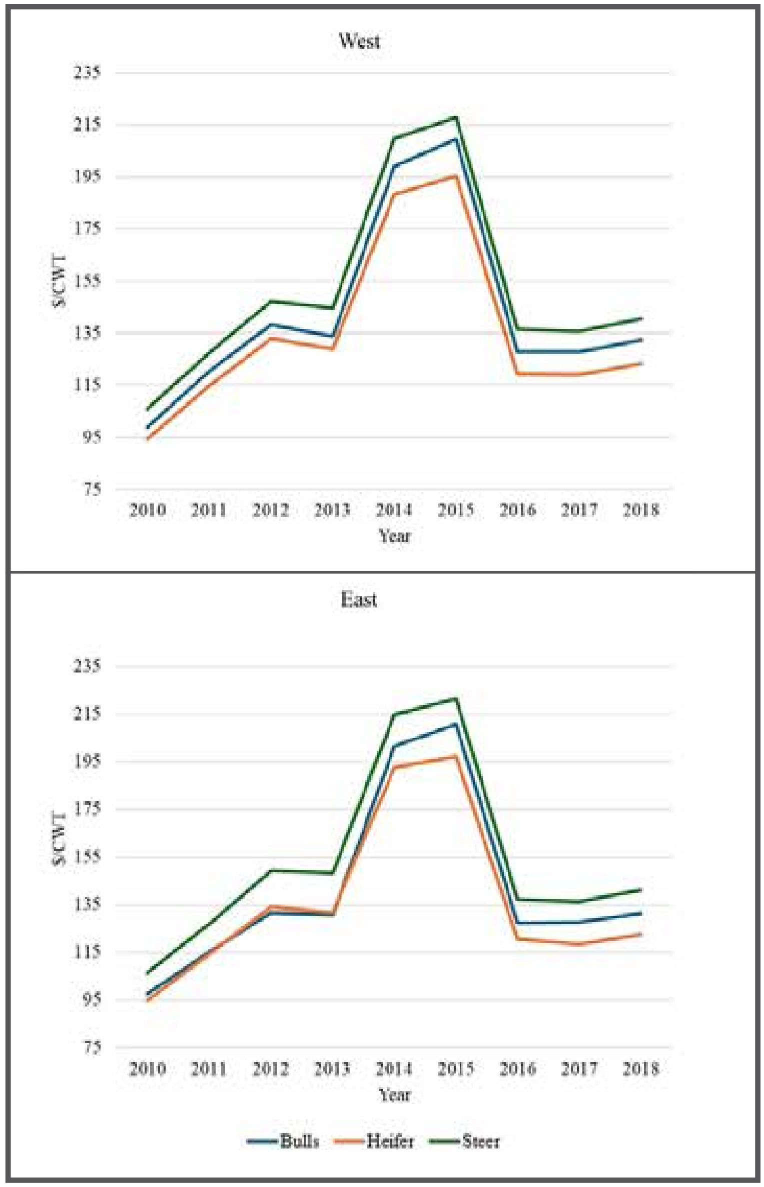


Figure 2. Yearly number of transactions in the West (above) and East (below) by steers, bulls and heifers

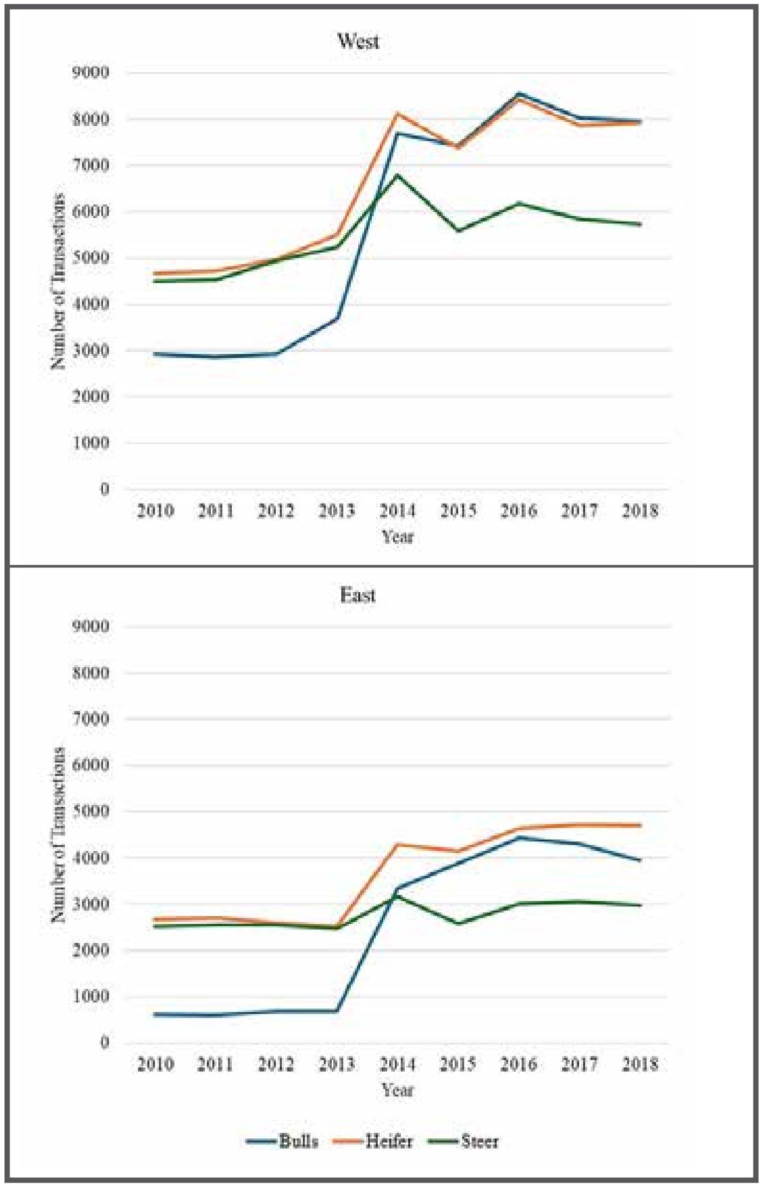


Figure 3. Yearly number of cattle sales transactions in the West (above) and East (below) by steers, bulls, and heifers

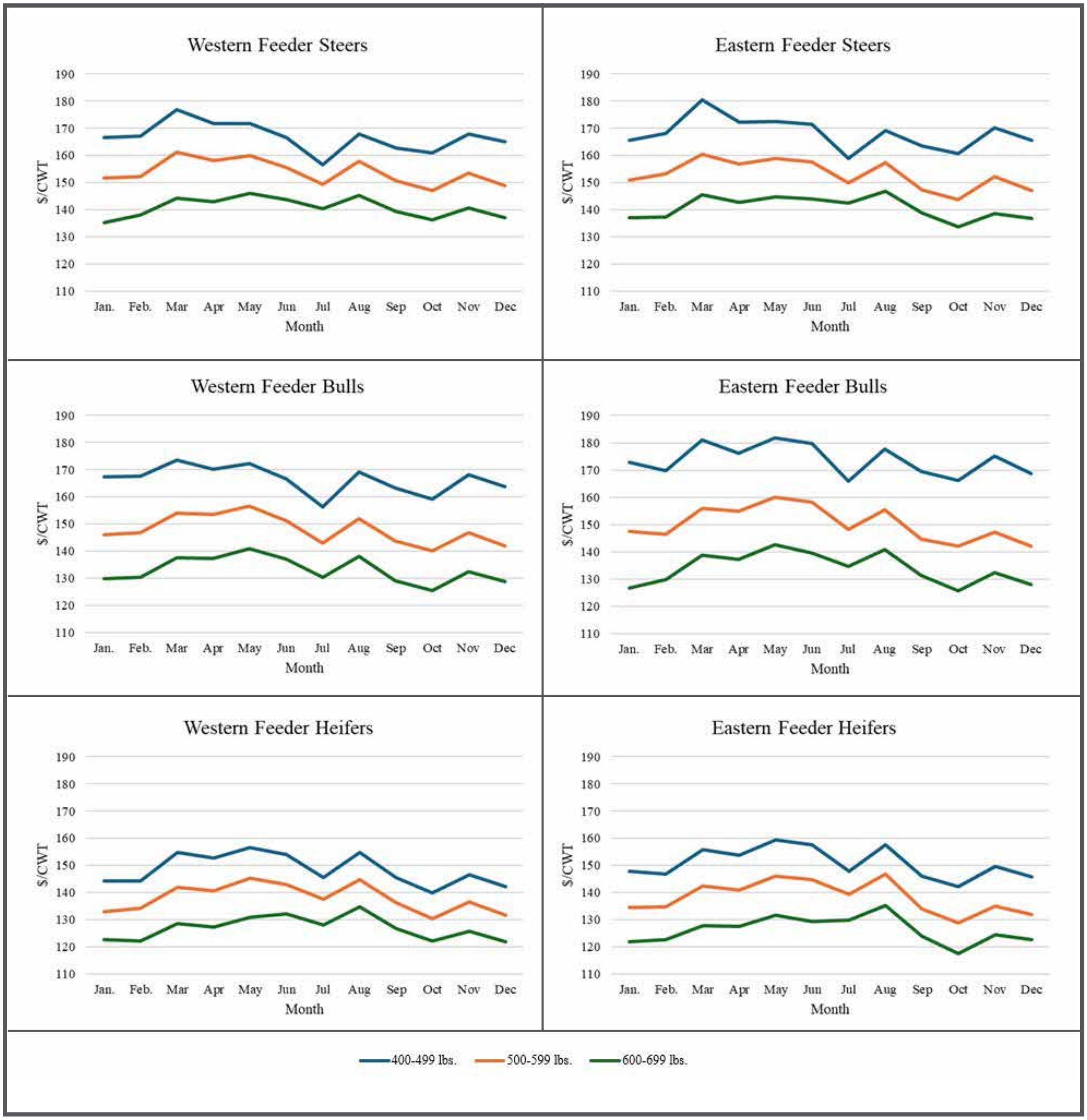
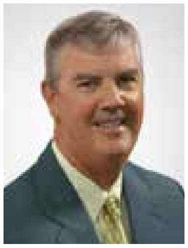
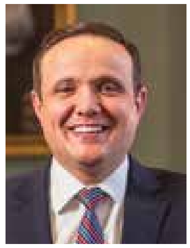


Figure 4. Seasonal price patterns for cattle sold in the West (left) and East (right) with steers (row 1), bulls (row 2), and heifers (row 3) by weight (400-499 lbs., 500-599 lbs., 600-699 lbs.)

Figure 5. Seasonal transaction volume for cattle sold in the West (left) and East (right) with steers (row 1), bulls (row 2), and heifers (row 3) by weight (400-499 lbs., 500-599 lbs., 600-699 lbs.)

Surveyed Factors Influencing Ranch Transition Planning

We surveyed ranchers across the United States to identify attributes of effective ranch transition plans and factors resulting in successful transition planning. The results indicate males and respondents over 50 years old are more likely to have a transition plan. Results also show net worth and operational structure each have a relationship with the presence of a transition plan.

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Abstract

A ranch transition plan describes the actions undertaken to transfer an operation to the next generation. Transition planning comes with many challenges; however, the presence of a transition plan is essential for ranch survival into the next generation.

INTRODUCTION

A ranch transition plan describes the actions that will be undertaken to transfer an operation from one generation to the next. A successful transition plan accomplishes two overarching goals: 1) the next generation assumes ownership and management of a viable operation, and 2) the older generation is provided a source of income in retirement. Transition planning often comes with many challenges and considerations; however, the presence of a transition plan is essential for ranch survival into the next generation.

Research from the Family Business Institute found that 30% of family-owned and operated businesses successfully transfer ownership and control of their business from the first generation to the second generation; 12% successfully transfer from the second to the third generation; and only 3% make it from the third to the fourth generation (Reed et al., 2021). Similarly, the Small Business Administration reports less than 33% of family businesses survive to the second generation, and only about 16.5% survive to the third (Craig, 2013). A study from 2021 argues inadequate transfer plans—or lack of a transfer plan—explains the low success rates of continued operation under the same family ownership, despite many producers' stated desire to keep their farm or ranch in one piece and in the family (Reed et al., 2021). A 2013 *Farm*

Journal survey reported that 80% of surveyed farmers planned to transfer operational control to the next generation, but only 20% of them were confident their succession plan would achieve that goal (Craig, 2013).

Transition planning is difficult for several reasons—it is time-consuming and often requires legal and accounting expertise—but the main reasons are psychological. Transition planning requires people to face their own mortality and make decisions their family, usually their children, may find disagreeable, such as leaving ranch assets to one child but not the other(s). Rather than upset family members or contemplate their inability to ranch forever, producers tend to delay planning altogether (Conway et al., 2019). This creates more problems for heirs when the older generation passes away, especially in cases with a mix of on-farm and off-farm heirs. On-farm heirs work for and/or plan to continue the family ranch, while off-farm heirs leave the ranch. The distinction between on- and off-farm heirs is not binary in all cases: an heir may contribute to the family ranch or have ownership in the ranch without physically living or working on the ranch. Contributions could be financial or an offering of services in another area of expertise, i.e., lawyer, accountant, financial advisor, livestock or crop consultant, or economist.

An adequate transition plan includes details regarding transfer of both management (succession plan) and assets (estate plan). Without an adequate succession plan, roles and responsibilities are poorly articulated and distributed, leaving heir(s) at a disadvantage when the older generation is gone. Without an adequate estate plan, state intestacy laws take effect which may or may not reflect the wishes of the deceased. In many states, intestacy laws give heirs an undivided, equal interest in ownership of assets (Texas Estates Code, n.d.). If these assets are cash or stocks, they can be easily divided and distributed equally to heirs. However, the 2023 U.S. farm balance sheet data reports the largest component of total farm assets is land (83.7%); machinery and vehicles make up 8.3% of farm assets; and animal inventories make up 3.1% (USDA ERS, 2023). The actual value of these assets is only realized when sold, which presents a challenge to on-farm heirs if ownership of farm assets is divided between a mix of on-farm and off-farm siblings.

In the case of two siblings, one on-farm and one off-farm, it is not as simple as selling half the land, half the machinery, and half the cow herd to compensate the off-farm heir. Land is highly variable in terms of value. Half the acres may be cropland or contain the major water source for the operation while the other half is pasture, and all may be necessary to maintain the cow herd. Selling half the machinery is problematic if the ranch retains the same equipment requirements, and cow herd size is often a strategic number that is necessary to sustain viable cash flow. With undivided interest between on- and off-farm siblings, the on-farm heir must "buy out" the off-farm heir to keep the ranch assets together. Ranch net worth values discussed in this study range from hundreds of thousands of dollars to over $20 million. Therefore, it may be infeasible for the on-farm heir(s) to purchase the remaining interest in farm assets from the off-farm heir(s), thus diminishing the likelihood of transition success. Avoiding this outcome and other unfavorable consequences requires planning. The objective of this study is to determine attributes of effective ranch transition plans and observe factors encouraging versus inhibiting transition planning through analysis of a survey of U.S. ranchers. The results include examples of successful transition plan strategies that may serve as helpful tools to producers who are in the planning process.

BACKGROUND

A 2000 survey asked Iowa farmers about their succession plans; most survey respondents were middle-aged males (average age of 54) and the sole proprietors of their farm business (Duffy et al., 2002). Regarding retirement plans, 27% claimed they intended never to retire. Respondents reporting plans for full or semi-retirement intended to rely on Social Security benefits and private retirement plans for income; however, most retirement income was expected to come from continued operation or sale of the farm. Respondents indicated an average retirement age of 66; however, 50% had no estate plan, and 71% had not yet chosen a successor. Of the 29% who had named a successor, 79% named their sons, 6% named their daughters, 6% named their sons-in-law or daughters-in-law, and 8% listed "other." More than half of respondents said their successors are currently employed off the farm—the authors anticipated this would complicate the management transition process, especially considering more than half the respondents had not discussed their retirement plans with anyone.

In the 2001 Agricultural Resource Management Survey, farm operators were asked whether they had developed a succession plan for their operation. A 2010 study analyzed a subset of these survey responses from married households with operators over 45 years of age (Mishra et al., 2010). The authors found factors significantly influencing operators' decisions to have a succession plan included age of operator, educational attainment of operator, off-farm work by operator or spouse, expected household wealth, and regional location of the farm business. The authors advised economists, financial planners, and farm business consultants to help farm operators improve succession decisions by outlining clear steps to follow and providing examples of succession plans from other family farms.

Results from Minnesota farm transition workshops showed 58% of attendees did not have an up-to-date estate plan, and 89% did not have an up-to-date farm business transfer plan (Hachfeld et al., 2009). Participants were asked to list barriers they encountered in business transfer and estate planning. Time was the number one obstacle for the majority of those who had not begun the planning process. Other barriers included the following:

- Developing goals,
- Consensus among family members and disagreement between heirs,
- Difficulty finding the right professionals (lawyers, accountants, bankers, consultants) to help, and
- Parents unwilling or not yet ready to retire and give up control.

Using a qualitative interview approach, a farm succession study in Texas found that farm succession methods vary considerably due to individual family dynamics (Lange et al., 2016). In seven farm family interviews, the most discussed topic was the allocation of management responsibilities, which varied greatly. In some cases, the younger generation acted only as hired labor for the older generation and had no managerial control. In other families, the two generations each had their own, separate farming businesses but shared equipment and resources. Still in other cases, the younger and older generations shared management responsibilities of one farm based on strengths and interests—the older generation was often more equipped to handle financial decisions, and the younger was more skilled in production practices. This delegation of management allowed the younger generation to learn from the older and still have buy-in as a decision maker on the farm.

These interviews also addressed the future of ownership and operation, with multiple children in all participating families. In all but one case, families indicated children would be compensated approximately equally whether with a portion of the farm business or monetarily. In the case of the family indicating unequal distribution of farm management and assets among the children, the principal operator indicated management and stock ownership were proportional to the amount of work each stakeholder had put into the business. When asked about retirement, interviewees were again diverse in responses. Most members of the older generation claimed retirement was very far in the future, and the younger generation was skeptical the older generation would ever completely retire from farming. Some admitted they had not thought much about succession and inheritance processes.

Farm succession research in England also took a qualitative interview approach and found two distinct modes of transfer of managerial control: conservative and progressive (Chiswell, 2018). Conservative transfer successors experienced a ladder of increasing responsibility with financial decisions as the final, sometimes unattainable, rung. Despite heavy involvement in the day-to-day operation of the farm, some successors had little to no input in financial decisions and were often met with parental resistance during their ascent up the ladder. On the other hand, progressive successors had been simultaneously incorporated into all aspects of farm management. Progressive successors, generally a younger group, seemed to view coming back to the farm as more of a choice. Their parents had encouraged them to get an education and try other professions, then come back to the farm if they desired. These successors felt they had ownership of their decision to be on the farm. Since successors had other options, the incumbent farmers were more inclined to engage them in all aspects of the operation to safeguard their interest, and therefore, the likelihood of succession. This progressive approach also gave incumbent farmers a chance to see their successor's capabilities, and they looked forward to retirement knowing the farm would be in good hands.

In a survey of Texas agricultural landowners, most respondents said their land had been in their family for more than 100 years, and their biggest concern for the future was that the land would be sold (Benavidez and Lashmet, 2023). Other respondents expressed concern about the qualifications of heirs and concern about taxes—specifically estate taxes, capital gains taxes, and property taxes.

Results from previous farm transition planning surveys are missing examples of real-world transition plans that could be helpful to producers in the planning process. This study provides results from a transition planning survey and details of plans producers are implementing.

DATA AND METHODOLOGY

Survey Data

Data for this study was collected through a survey of U.S. ranchers and owners of ranching lands. The survey was intended for ranchers and landowners of all ages and operation sizes, and this study was approved by the Texas A&M University Institutional Review Board (protocol number: IRB2023-0510M). Survey responses were collected from 179 participants, and of those, 148 surveys were completed. The survey design allowed participants to skip questions, but a survey was considered "completed" if the participant was presented with each question and clicked "submit" at the end of the survey. Only the completed surveys are considered in the analysis.

Survey Design

The survey included both multiple choice and open response questions. The survey contained four sections:

1. Producer Information – questions about the ages and roles of the owner/operator and other family members on each ranch.
2. Operation and Financial Information – questions about the net worth of the operation, the number of individuals dependent on ranch income, land inheritance, federal estate taxes, and structure of the operation.
3. Succession Planning – questions about heirs and whether a succession plan is in place, as well as open-ended questions for participants to describe their succession plan or list roadblocks to succession planning.
4. Other Estate Planning Questions – questions about wills and other end-of-life documents.

This study utilized Qualtrics for survey design and implementation. Survey distribution avenues included email, e-newsletters, social media, and in-person interactions at the Texas A&M University Beef Cattle Short Course. The survey was accessed using either a QR code or an anonymous link, and responses were collected between June 29 and August 31, 2023.

The chi-square test of independence was used to examine the relationship between each variable and the succession plan variable. The chi-square test of independence determines whether two categorical variables are independent from or associated with each other. The null hypothesis for the chi-square test of independence is that the variables of interest are independent from each other. The alternative hypothesis is that the variables of interest are associated with one another (Franke et al., 2012). The chi-square test was employed in this study to show which variables are associated with the succession plan variable to provide information about the population that has a succession plan. For example, if age is associated with the presence of a succession plan, and more older respondents have a succession plan than younger respondents, then the results indicate that older people are more likely to have a succession plan. This information along with responses to the open-ended questions may lead to improved development and allocation of succession planning education and resources.

RESULTS

The following subsections summarize survey responses and provide the results of chi-square tests for independence of each variable from succession planning. Of the 148 participants, 57 (38.5%) have a succession plan and 89 (60.1%) do not; two participants did not answer this question. Participants' free responses regarding succession planning and roadblocks to planning are also summarized.

Producer Information

Responses from the "Producer Information" section of the survey are summarized in Table 1. Most respondents were over 50 years old (65.6%). Of the 148 completed surveys, 99 (66.9%) participants were from Texas, 29 (19.6%) were from other states, and 20 (13.5%) did not respond to this question. Over 70% of respondents were male, and 28.4% were female. Chi-square tests of independence indicate significant relationships between gender and succession planning and age and succession planning (see p-values in Table 1). Responses indicate males are more likely to have a succession plan than females, and respondents over 50 years old are more likely to have a succession plan than those under 50 (Figure 1).

Chi-square tests between the other "Producer Information" variables and succession plan presence failed to reject the null hypothesis (at the 0.05 significance level) that each variable is independent from the succession plan variable. These variables include role in the operation, marital status, number of children, and whether children are engaged in the operation. At the 0.10 significance level, the null hypothesis is rejected by the chi-square test regarding whether children are engaged in the operation. Therefore, results indicate that respondents are less likely to have a succession plan if they do not have children engaged in the operation. Of participants with children, 43.4% have at least one child engaged in the operation.

Financial Information

Responses from the "Financial Information" section of the survey are summarized in Table 2. Almost 30% of operations have a net worth below $1,000,000; 29.7% have a net worth between $1,000,000 and $4,999,999; 19.6% have a net worth between $5,000,000 and $9,999,999; and 19.6% have a net worth greater than $10,000,000. The chi-square test of independence between net worth and presence of a succession plan indicates there is a relationship between the two variables. Survey results show an increasing percent of respondents with a succession plan as net worth increases, until net worth reaches $15,000,000. Figure 2 shows the respondents' distribution of net worth and presence of a succession plan.

For the distribution of timing of land inheritance by respondents, the categories "all prior to," "most prior to," "some of each," "most following," and "all following" are used to indicate timing of inheritance relative to the death of the previous owner. "None" indicates respondents have not inherited any land. Most respondents inherited land after the death of the previous owner (30.4%) or have not inherited any land (44.6%). The majority (56.8%) of respondents answered "yes" to the question, "Has your family been able to avoid paying the federal estate tax when someone died in the past 50 years because the value of the estate fell below the exemption amount?" Neither the timing of land inheritance nor previous federal estate tax exemptions are found to be related to the presence of a succession plan.

Respondents provided answers regarding operational structure and were allowed to select multiple responses. Of 61 respondents who operate a sole proprietorship, 57 operate only a sole proprietorship, while four participants also operate in an organized structure. Structure of the operation is related to presence of a succession plan by the chi-square test of independence. For example, most sole proprietor respondents do not have a succession plan (73.8%). However, of respondents with operations in a partnership, LLC, or corporation, the percentage of respondents without a succession plan drops to 52%. Operations in a living trust or some "other" operational structure have the lowest percentage of respondents without succession plans (21.4% and 44.4%, respectively). These results indicate a positive relationship between operational structure and succession planning, i.e., producers who have put in time and effort to organize their operation beyond a sole proprietorship are more likely to have a succession plan. Figure 3 shows the distribution of responses regarding operational structure and presence of a succession plan.

Succession and Estate Planning

Responses from the "Succession Planning" and "Estate Planning" sections of the survey are summarized in Table 3. Most respondents (87.1%) have identified at least one heir to their operation; however, over half of respondents (60.1%) do not have a formal, documented succession plan in place. Over half of respondents (63.5%) have a will, and of those respondents, 93.5% said their will was drafted by an attorney. Over 50% of respondents have an advanced healthcare directive, and over 50% of respondents have a medical power of attorney. Fewer respondents have a durable power of attorney (45.9%). Only 14.2% of respondents utilize a transfer on death deed (TODD).

The chi-square test of independence shows most estate planning variables are associated with the presence of a succession plan, including having a will, an advanced health care directive, a medical power of attorney, a durable power of attorney, a TODD, and long-term care plans. Most of these are end-of-life documents that require an attorney. If respondents are consulting with attorneys and making end-of-life plans, it seems reasonable they would also have a succession plan. A chi-square test of independence also shows a relationship between number of anticipated heirs and presence of a succession plan (at the 0.10 significance level). Likelihood of having a succession plan is lower for those with no heirs identified and with five or more anticipated heirs than for those with between one and four anticipated heirs. Figure 4 shows the respondents' distribution of number of heirs and the presence of a succession plan.

Succession Plan Free Responses

The free-response question in the survey regarding details of respondents' succession plans provides information that contributes to the succession planning survey literature. The first free-response question asked participants to describe their succession plan. Understanding how other producers are planning for succession may benefit those in early transition planning stages. Common themes in producer responses are listed below:

1. Utilizing a trust to protect and transfer assets and the control of assets.
2. Plans to transfer all ranch assets and management control to the on-farm heir(s) and divide all personal assets between all heirs.
3. Utilizing an LLC, corporation, or partnership to facilitate lifetime transfer and incorporate on-farm heir in management and ownership during the life of the senior generation.
4. Utilizing an LLC, corporation, or partnership to create membership agreements and/or set restrictions. Examples of restrictions include:
   a. Must be a blood relative to own shares.
   b. Must be actively involved to receive or own shares.
   c. If one shareholder wants to sell their shares, they must sell to the other shareholders or a blood relative for a set percentage below the appraised fair market value.
   d. Sale of land/assets requires a unanimous vote from all shareholders.
5. Lifetime, or *inter vivos*, transfer of shares to on-farm heirs, whether purchased by or gifted to the upcoming generation.

Roadblocks to Succession Planning

Survey participants also responded to an open-ended question regarding roadblocks to succession planning. Common themes in producer responses include:

- Resistance from senior generation,
- Lack of time or failing to make time to plan,
- Lack of knowledge or education in succession planning,
- Finding professional help (accountant, attorney, or financial planner) knowledgeable in succession and estate planning,
- Legal fees,
- Determining how to leave ranch assets to on-farm heirs and provide equitable assets to off-farm heir,
- Lack of a successor or children are not interested in continuing the business,
- Predicting the future generation's interest in the ranch (pertains to producers with young children),
- Lots of owners or shareholders–difficult to manage,
- Family dynamics, conflict, lack of communication, and avoidance of uncomfortable conversations, and
- Difficult land or asset structure.

CONCLUSION

Literature and anecdotal evidence agree that there are low success rates of intergenerational farm and ranch transitions, and most producers lack an adequate transition plan. The survey in this study was designed to determine characteristics of successful transition plans, demographics of producers with transition plans in place, and common roadblocks to transition planning. The purpose of identifying characteristics of successful transition plans is to develop general guidelines and share ideas with producers beginning or struggling to make plans. The purpose of observing demographics of producers with transition plans is to provide more targeted educational resources and assistance to groups that need it. Finally, the purpose of gathering information on transition planning roadblocks is to identify the areas of transition planning where producers need more resources.

The results support the literature in that most respondents do not have a ranch transition plan. Responses indicate relationships between some producer and operational characteristics and presence of a succession plan. Results also indicate males are more likely to have a succession plan than females, and respondents over 50 years old are more likely to have a succession plan than those under 50. In addition, results show an increasing percent of respondents with a succession plan as net worth increases, until net worth reaches $15,000,000. Structure of the operation is also related to presence of a succession plan: the more sophisticated the operational structure becomes, the more likely there is a plan in place. These findings indicate some transition planning resources should be developed for and presented to younger producers, those with lower net worth, and producers with less organized operational structures.

The examples of transition planning successes and roadblocks provided in the open-ended responses could inform future education programming and resources for producers. Several of the roadblocks to transition planning noted by producers confirmed those observed in previous work, namely, resistance from senior generations, making time to plan, challenging family dynamics, or lack of a successor. Answers to free-response questions show transitioning a ranch is not a one-size-fits-all process; however, there are common hang-ups that educators and professionals could help producers work through.

The survey results provide insights on some ranch transition strategies producers use. While this study focused on ranches, family operations in the crop farm and agribusiness sectors also face intergenerational transfer challenges. Future success across agricultural sectors hinges on the survival of agricultural operations. To help their operation survive to the next generation, producers should create a transition plan tailored to their operation considering unique family dynamics, ownership and management structures, and goals. To support and encourage transition planning in the agricultural industry, resources and outreach could be developed to help producers navigate the transition planning process. This could include planning guides, workshops, collaborations with accountants and lawyers to create tax and law resources, and connecting producers to professionals with experience in transition planning. Policymakers and agriculture groups could support development of these resources through funding of agricultural Extension programs.

There are still several gaps to fill in determining what will incentivize producers to develop transition plans and what kind of assistance they need to do so. Future research should aim to seek more information about where transition planning resources should be allocated and what those resources should include.

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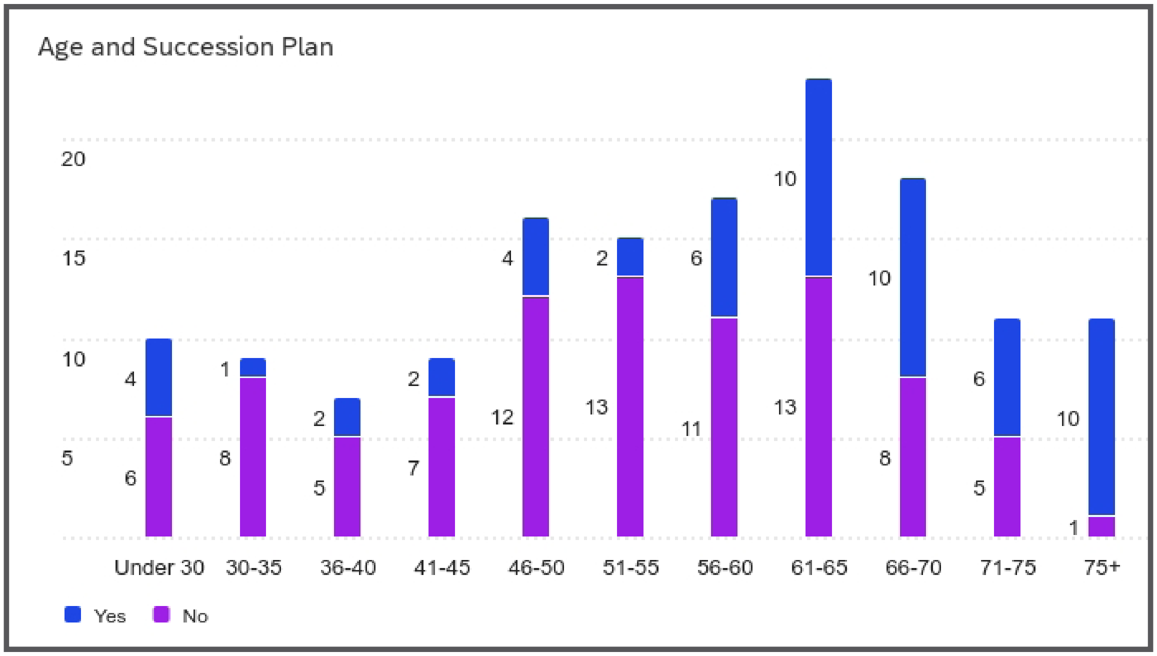


Figure 1. Distribution of producer age and presence of a succession plan

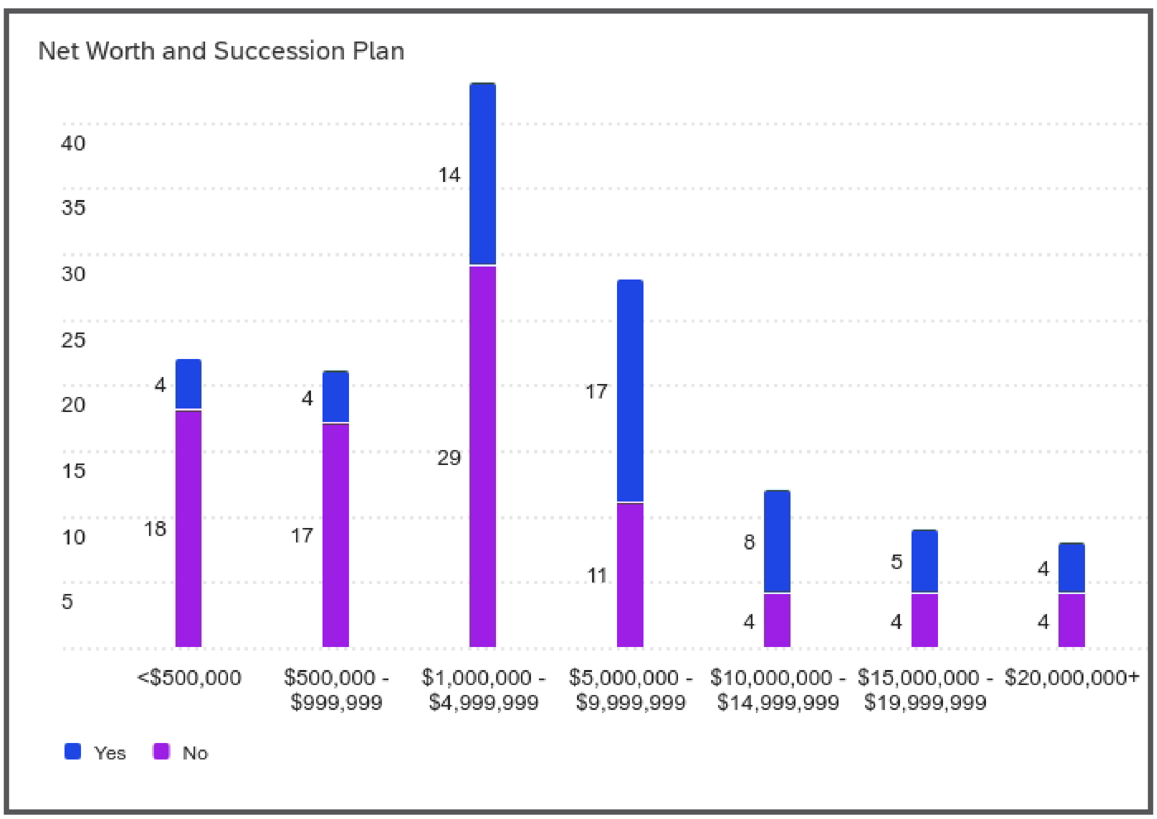


Figure 2. Distribution of net worth and presence of a succession plan

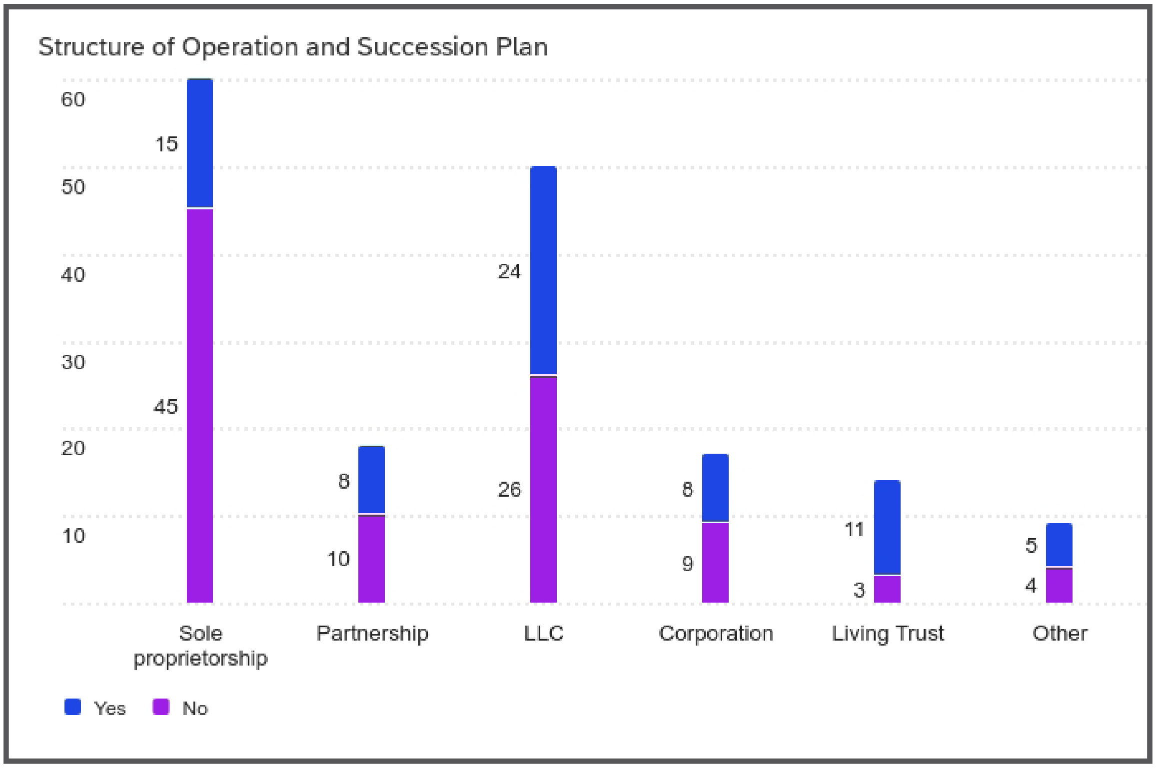


Figure 3. Distribution of operational structures utilized and presence of a succession plan

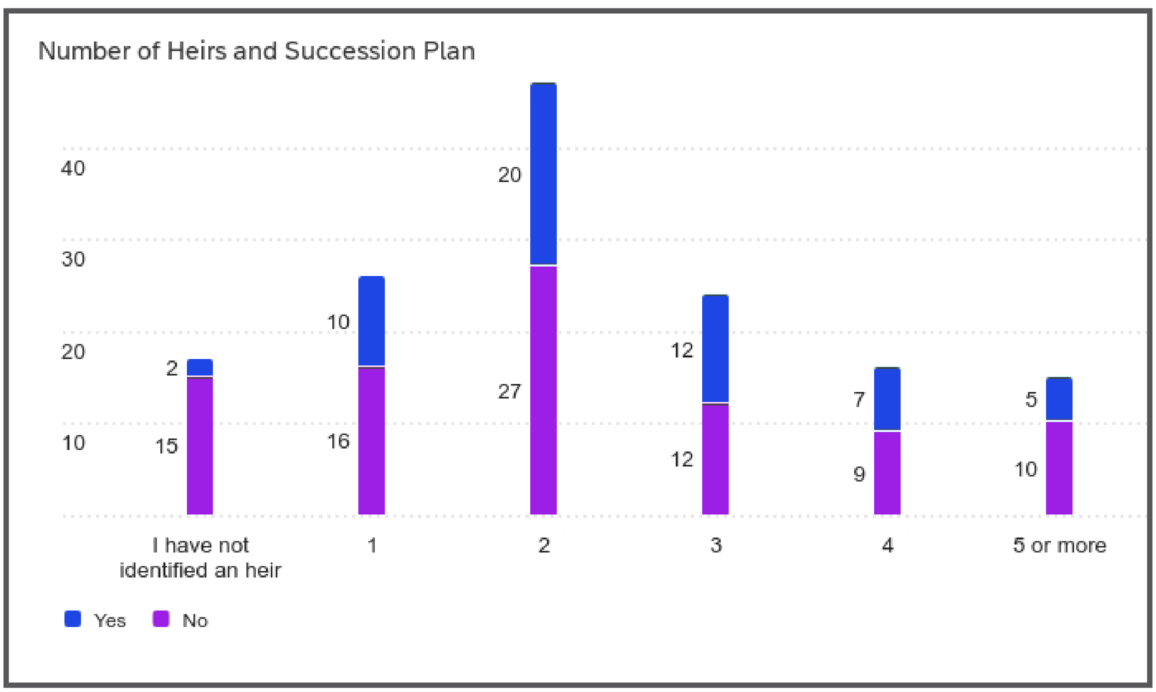


Figure 4. Distribution of number of heirs and presence of a succession plan

Table 1. Summary of Producer Information

Item			Plan		No Plan		X^2
	No.	Pct.[a]	No.	Pct.	No.	Pct.	p-value
Number of Respondents (Completed Surveys)	148						
State							
Texas	99	66.9	32	32.3	66	66.7	
Other	29	19.6	17	58.6	11	37.9	
Gender							.0271*
Male	105	70.9	46	43.8	58	55.2	
Female	42	28.4	10	23.8	31	73.8	
Age							.0139*
50 and under	51	34.5	13	25.5	38	74.5	
Over 50	97	65.6	44	45.4	51	52.6	
Role in Operation							.7444
Owner	49	33.1	22	44.9	27	55.1	
Primary manager	19	12.8	7	36.8	11	57.9	
Both	70	47.3	24	34.3	45	64.3	
Neither	10	6.8	4	40.0	6	60.0	
Marital Status							.2683
Married	124	83.8	47	37.9	75	60.5	
Single	19	12.8	6	31.6	13	68.4	
Widowed	4	2.7	3	75.0	1	25.0	
Number of Children							.5989
None	26	17.6	8	30.8	18	69.2	
1	18	12.1	8	44.4	10	55.5	
More than 1	104	70.3	41	39.4	61	58.7	
Are Children Engaged in the Operation?[b]							.0823**
Yes	53	43.4	26	49.1	27	50.9	
No	68	55.7	22	32.4	44	64.7	

*Significant at 0.05 level.

** Significant at 0.10 level.

[a] Response percentages do not all add to 100%, some participants did not answer every question.

[b] Only participants with at least one child responded to this question.

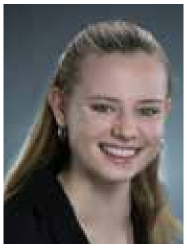
Table 2. Summary of Financial Information							
Item			Plan		No Plan		X^2
	No.	Pct.[a]	No.	Pct.	No.	Pct.	p-value
Number of Respondents (Completed Surveys)	148						
Net Worth of Operation:							0.0040*
Below $500,000	22	14.9	4	18.2	18	81.8	
$500,000 - $999,999	21	14.2	4	19.0	17	81.0	
$1,000,000 - $4,999,999	44	29.7	14	31.8	29	65.9	
$5,000,000 - $9,999,999	29	19.6	17	58.6	11	37.9	
$10,000,000 - $14,999,999	12	8.1	8	66.7	4	33.3	
$15,000,000 - $19,999,999	9	6.1	5	55.6	4	44.4	
$20,000,000+	8	5.4	4	50.0	4	50.0	
Number of Individuals Dependent on Ranch Income:							0.2275
None	81	54.7	27	33.3	53	65.4	
1 - 2	31	20.9	14	45.2	17	54.8	
3 - 4	21	14.2	7	33.3	13	61.9	
5 or more	15	10.1	9	60.0	6	40.0	
Timing of land inheritance relative to death of the previous owner:							0.1095
Most or all inherited prior to	25	16.9	10	40.0	15	60.0	
Some inherited prior to, some after	12	8.2	8	66.7	4	33.3	
Most or all inherited after	45	30.4	19	42.2	25	55.6	
Have not inherited any land	66	44.6	20	30.3	45	68.2	
Able to avoid federal estate tax in last 50 years due to estate value?							0.1758
Yes	84	56.8	35	41.7	47	56.0	
No	29	19.6	13	44.8	16	55.2	
Unsure	35	23.6	9	25.7	26	74.3	
Structure of Operation (multiple selections allowed):							0.0058*
Sole proprietorship	61		15	24.5	45	73.8	
Partnership	19		8	42.1	10	52.6	
LLC	50		24	48.0	26	52.0	
Corporation	17		8	47.1	9	52.9	
Living Trust	14		11	78.6	3	21.4	
Other	9		5	55.6	4	44.4	

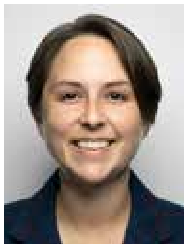
*Significant at 0.05 level.

Table 3. Summary of Succession Planning and Estate Planning Responses							
Item			**Plan**		**No Plan**		**X^2**
	No.	**Pct.**[a]	**No.**	**Pct.**	**No.**	**Pct.**	**p-value**
Number of Respondents (Completed Surveys)	148						
Number of Anticipated Heirs							0.0762**
1 - 2	74	50.0	30	40.5	43	58.1	
3 - 4	40	27.0	19	47.5	21	52.5	
5 or more	15	10.1	5	33.3	10	66.7	
No heirs identified	18	12.2	2	11.1	15	83.3	
Succession Plan							
Yes	57	38.					
No	89	60.1					
Will							2.38e-6*
Yes	94	63.5	49	52.1	45	47.9	
No	51	34.5	6	11.8	44	86.3	
Advanced Healthcare Directive							0.0003*
Yes	87	58.8	44	50.6	42	48.3	
No	44	29.7	7	15.9	37	84.1	
Unsure	14	9.5	4	28.6	10	71.4	
Medical Power of Attorney							2.63e-6*
Yes	85	57.4	47	55.3	38	44.7	
No	52	35.1	7	13.5	44	84.6	
Unsure	8	5.4	1	12.5	7	87.5	
Durable Power of Attorney							2.53e-6*
Yes	68	45.9	40	58.8	28	41.2	
No	64	43.2	10	15.6	53	82.8	
Unsure	12	8.1	4	33.3	8	66.7	
Transfer on Death Deed							0.0004*
Yes	21	14.2	15	71.4	6	28.6	
No	101	68.2	28	27.7	72	71.3	
Unsure	22	14.9	11	50.0	11	50.0	
Long-Term Care Plans (multiple selections allowed)							0.0193*
No current plan	43	29.1	10	23.3	32	74.4	
Plan:	103	69.6	46	44.7	57	55.3	
Retirement accounts	82		34	41.5	48	58.5	
Medicaid	24		9	37.5	15	62.5	
Long-term care insurance	30		16	53.3	14	46.7	
VA benefits	9		4	44.4	5	55.6	

*Significant at 0.05 level.
**Significant at 0.10 level.

Spatial Exploration of Drivers in Maryland's Commercial Poultry Production





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Abstract

Poultry is the most consumed meat in the United States, with the Delmarva region (Delaware, Maryland's Eastern Shore, and Virginia's Eastern Shore) being a key production hub. This study utilizes spatial and economic analysis to examine heterogeneous factors driving broiler production concentration at the Census block group level, including geophysical characteristics, production infrastructure, and demographic patterns in Maryland. Data for the analysis was collected and updated through Spring 2024, and all analysis was conducted in 2024. The resulting findings and visualizations offer farm managers and consultants a tool for assessing broiler production dynamics. This research provides insights that can shape land use planning, resource allocation, and technical assistance programs in regions characterized by intensive commercial broiler production, as well as supporting informed policy decisions.

INTRODUCTION

Poultry production has evolved over the last half-century from dual-purpose backyard birds to highly specialized, integrated systems with regional production centers. Domestic poultry production surpassed beef and pork in the late 1990s to become the highest-consumed protein in the United States (U.S.) (Livestock Marketing Information Center, 2022). Broilers, chickens raised for meat, are birds selectively bred for their muscle composition, rapid growth rate, and hardiness. Additionally, broilers are highly efficient in converting feedstock energy into meat products for human consumption, outperforming other livestock meat sources, including cows and pigs, in feed-to-meat conversion rates (ERS, 2023).

Vertical integration and increased demand for chicken meat has led to increased production levels and intensification of production, with some notable spatial patterns. The structure of the poultry industry and integration lead to transportation efficiencies and location strategies that minimize costs in moving birds from houses to processing and the customer (MacDonald, 2014). The continued increase in demand for poultry products, domestically and globally, has further intensified broiler growth in the U.S. Currently, broiler production is predominantly located in Southern states, with Georgia, Alabama, and Arkansas as the top three and Maryland in the top ten (USDA NASS, 2024b). Further, all of Maryland's commercially concentrated broiler production is on the Eastern Shore, part of the Delmarva Peninsula region, which includes all of Delaware, the Eastern Shore counties of Maryland, and the Eastern Shore counties of Virginia (USDA NASS, 2024b).

Figure 1 illustrates 2022 broiler production, measured as chicken sales, in headcount, at the county level as adapted from the United States Department of Agriculture's National Agricultural Statistics Service's (USDA NASS) Census of Agriculture (USDA Census Bureau, 2024b). The prominence of these production regions stems from the locations of growers, integrators, and supply chains that distribute broiler products to the market. By analyzing Maryland's Concentrated Animal Feeding Operation (CAFO) permits, this study develops a geodatabase and estimates broiler production's economic and geographic drivers at the Census block group level. Using Maryland as a case study, our analysis provides novel insights into the spatial dynamics of broiler production.

Background

Today, broiler production is concentrated in the Southern U.S. region (Georgia, Alabama, Florida, and South Carolina), which, in 2023, accounted for 30.95% of national broiler output (USDA NASS, 2024b). The Southern region is followed by the Delta (Arkansas, Louisiana, and Mississippi) and Eastern Mountain regions (Kentucky, North Carolina, Tennessee, Virginia, and West Virginia) (USDA NASS, 2024b). The industry's interdependence with corn and soybean production is pivotal, as broiler feed predominantly consists of these two commodities. Additionally, improved feed conversion efficiency, further optimized feed rations, and economies of scale in recent decades have played an increasingly critical role in the cost efficiency of broiler production (MacDonald, 2014; Mallick et al., 2020).

While commercial-scale broiler production is nationally distributed, it is spatially concentrated in several, distinct regions, as illustrated in Figure 1. Maryland is a notable case study for its legacy of balancing intensive food production and environmental stewardship, particularly its efforts to protect the Chesapeake Bay. Today, approximately 47.9% of the state's agricultural market value is tied to poultry production (USDA NASS, 2024b). More specifically, cash receipts from poultry and eggs were valued at approximately $1.6 billion in both 2017 and 2022 NASS Census results, positioning Maryland as the seventh-largest broiler producer in the U.S. (USDA NASS, 2024b).

Perdue Farms, founded and based in Salisbury, Maryland, was instrumental in the growth of the Delmarva broiler industry. In the 1960s, the company invested in grain and soybean processing and, in 1968, opened its first processing plant (Perdue, 2024). Perdue further advanced the industry by introducing the PERDUE® brand to the New York City market, which has had a lasting impact on poultry marketing and production. These efforts have contributed to the agricultural infrastructure that underpins Maryland's broiler industry today.

As the broiler industry has grown in scale and concentration, public access to agricultural data has become increasingly important. The Maryland Public Information Act, enacted in 2014, provides a valuable resource by granting public access to government records, including detailed data on business operations. This legislation offers insights into M/CAFOs, including broiler capacity—the maximum number of birds housed at a time—and the location of broiler operations with General Discharge permits. As outlined by COMAR 26.08.04.09N(3), these permits require operators to submit a Notice of Intent and necessary plans, which undergo public review through a public participation process. Maryland also distinguishes between two types of Animal Feeding Operation (AFO) permits: CAFOs and Maryland Animal Feeding Operations (MAFOs), each subject to different regulatory requirements.

According to a report by the Natural Resources Defense Council, Maryland and Tennessee stand out as the most transparent states regarding information and data on CAFOs (Devine and Baron, 2019; Lee Miller and Muren, 2019). Although efforts were made to collaborate with state agencies in Delaware and Virginia to obtain comparable data in 2024, we were informed that these states require residency to fulfill Freedom of Information Act requests, a restriction that prevented us from accessing data for the entire Delmarva region. As a result, our analysis relies exclusively on Maryland's M/CAFO, which is regulated and reported by the Maryland Department of Environment (MDE).

Integrating Geography and Economics

This research utilizes a novel approach to analyzing Maryland's broiler industry by integrating Geographic Information Systems (GIS) with applied agricultural economic models. The GIS toolbox and modeling techniques employed provide new insights into the spatial dimensions of the broiler industry, examining factors like land use patterns, soil health, and nutrient runoff risk zones. When coupled with agricultural economic models, these tools allow for an assessment of the financial viability of varying land management strategies, offering an untried framework for evaluating the industry's supply chains and their linkage to production and markets.

This integration provides a novel approach to addressing key challenges in regions like Maryland's Eastern Shore, where competing agricultural and environmental interests make land use decisions particularly complex. A comprehensive and systematic approach that combines the two fields while also addressing the sustainability of poultry litter management, as observed in studies that have used GIS-based decision support systems to enhance litter management, reduces nutrient runoff and optimizes transportation strategies (Kang et al., 2008).

A previously created visual representation of this concentration is shown in Figure 2, which maps all active M/CAFOs in Maryland in 2023. In Figure 2, the orange dots represent broiler M/CAFOs, all of which are located within the nine counties of Maryland's Eastern Shore, while dairy and beef cattle are distributed throughout the rest of the state. This regional concentration underscores broiler production's dominance on the Eastern Shore, where 86.9% of Maryland's poultry inventory is located in Worcester, Caroline, Somerset, and Wicomico counties (Lansing et al., 2023). The concentration of broiler production in these four counties raises pressing questions about its underlying factors and associated environmental and economic impacts, guiding these research efforts.

Building on literature like the work in "Synthesized Population Databases: A Geospatial Database of US Poultry Farms," GIS offers insights into managing CAFOs while also addressing gaps in available data about broiler production systems (Bruhn et al., 2012). As broiler production continues to expand, GIS resources can reveal patterns and relationships within data layers, such as considerations at the intersection of environmental management challenges like the identification of suitable land areas and timing for litter application and predicting nutrient exceedance risks due to increased production (Xu et al., 1993).

GIS facilitates the integration of diverse spatial data into a comprehensive database that supports sustainable farm management practices and improves the economic and ecological viability of agricultural systems (Rao et al., 2000). While much of the available information focuses on crop management, there is less data on CAFOs, particularly in broiler production, revealing a gap in the literature on CAFOs' regional impacts. Integrating GIS into the commercial broiler industry studies could enhance understanding of nutrient flows, land use pressures, and environmental effects, especially in regions where agricultural expansion faces ecological limitations (Zhang and Cao, 2019).

MATERIALS AND METHODS

This research uses an integrated GIS approach to analyze broiler production in Maryland at the Census block group level. The study consists of two key steps: (1) consolidation and integration of geophysical, production, and infrastructure information to each block group and (2) econometric modeling from the geodatabase. This section outlines the data sources, geographic extent, analytical processes, and econometric models employed.

Study Area

The study area focuses on Maryland's Eastern Shore, the state's primary area for commercial-scale broiler production. All broiler C/MAFOs are located exclusively in this region, making Maryland's Eastern Shore the natural focus for analyzing the dynamics of the state's broiler production. Covering approximately 3,800 square miles across nine counties, the Eastern Shore is largely agriculturally-focused, with a landscape anchored in corn and soybean production, which are key feed sources for broilers (Meyer, 2018).

The study region has a predominantly rural character, with an average population density of 138 residents per square mile, although there is significant variation. Salisbury, the region's largest city, exceeds 2,000 residents per square mile, while many areas are much less populated (Meyer, 2018). The Eastern Shore's demographic profile includes an older population, with 19% aged 65 or older, and a predominantly white population (73%), though Black and Latinx communities are growing (Meyer, 2018).

Data Sources and ArcGIS Pro Workflow

Under the Maryland Public Information Act, we accessed site-specific permitting data from MDE that regulates C/MAFOs that discharge pollutants into state waters. The permit data included permitted facility addresses, which were geocoded using the *ArcGIS World Geocoding Service* in ArcGIS Pro, integrated into our geodatabase, and aligned with other spatial datasets for analysis.

Demographic and geographic data were collected at the U.S. Census block group level, the smallest geographic unit for which the Census Bureau collects sample data. Block groups typically contain between 600 and 3,000 people and 240 to 1,200 housing units (US Census Bureau, 2024a). Using block groups as the observation unit enabled a more detailed analysis of localized demographic and socioeconomic factors as these datasets included population counts, racial demographics, and socioeconomic indicators, which provided insight into local variations in population that could influence resource allocation and decision-making on Maryland's Eastern Shore.

To analyze agricultural factors related to poultry feed production, we incorporated NASS's Cropscape – Cropland Data Layer (CDL), which provides a raster crop classification dataset. Corn and soybean acreage, as primary poultry feed sources, were estimated for both 2010 and 2020 (USDA NASS, 2024a). This was done using the *Summarize Categorical Raster* tool in ArcGIS Pro, which calculated the total number of pixels corresponding to corn and soybeans within each block group. Since each pixel in the NASS CDL represents 900 square meters (30 meters by 30 meters), pixel counts were multiplied by this area to estimate the total crop acreage in each block group. The data was then used to calculate the proportion of potential poultry feed sources by dividing the total corn and soybean acreage within each block group by the total corn and soybean acreage in Maryland.

In addition to agricultural acreage data, the study incorporated transportation infrastructure data to evaluate the accessibility of poultry-related industries to key transportation routes. Data on railroads and major highways, including interstates, Maryland state routes, and U.S. routes, was integrated into the geodatabase within ArcGIS Pro. The polyline shapefiles for these transportation routes were obtained from the Maryland Department of Transportation's GIS "Open Data Portal" (Maryland Department of Transportation, 2024), then filtered by type to only include federal interstates, state highways, and freight rail, which were then clipped within the boundaries of the block groups, allowing us to calculate the total length of railroads and highways within each block group. This was achieved using the *Calculate Geometry Attributes* tool in ArcGIS Pro, which provided the total length of transportation routes in kilometers, later converted to miles for reporting consistency. The transportation infrastructure data was integrated into the analysis to evaluate the logistical factors involved in transporting feed and poultry products and the impact of proximity to major transportation routes and market access on the location of high-capacity broiler operations.

The spatial analysis was conducted using various GIS tools within ArcGIS Pro to assess geographic relationships between poultry facilities, agricultural production, and transportation infrastructure. The *Near* function in ArcGIS Pro was used to calculate the Euclidean distance between the centroid of each block group and Salisbury, Maryland—the location of Perdue's corporate headquarters and poultry processing plant. Directional orientation data for each block group in relation to Salisbury was also calculated and classified into categories (North, South, East, West) to refine our understanding of spatial orientation.

Geodatabase Creation

After the spatial datasets were processed in ArcGIS Pro, Python was used to finalize data cleaning, summarization, and transformation for econometric analysis. The geospatial data, combined with population data from the 2010 and 2020 U.S. Census, was linked using National Historical Geographic Information System (NHGIS) crosswalk data to align block group boundaries over time (Manson et al., 2024). This involved merging the 2010 population data with the NHGIS crosswalk and applying interpolation weights to adjust population figures for changes in geographic boundaries. Population attributes such as total population and racial demographics were adjusted using these weights to ensure comparability across Census years. Null values were replaced with zero to ensure consistency across calculations.

After preprocessing in Python, the cleaned and processed data, including demographic, agricultural, and infrastructure variables, was stored in a single geodatabase. This geodatabase was then imported into Stata for the econometric analysis, where it was used to evaluate the impact of demographic and geographic factors on the poultry industry.

The data sources used for this study are summarized in Table 1.

Econometric Methodology

The objective of this study is to understand the heterogeneous factors contributing to broiler production in Maryland and how geospatial elements contribute to those production areas. However, many block groups have no level of poultry production, which leads to masses of zeros in the estimations. In order to econometrically model the factors influencing the concentration of broiler production in Maryland, we used a two-step process, where the first step models the likelihood of having birds in a block group, and the second step models the factors contributing to bird concentration. This two-stage process was first introduced by Heckman (1979). The process calculates an inverse mills ratio (IMR) as an intermediary step to account for sample biases used in the factor model, which truncates the data to positive poultry production by block group. To generalize the analysis, we account for the truncated data with the IMR. We briefly discuss the models used below.

The first stage uses a probit model on the binary variable *Production* and can be characterized as:

$$Production_i = \beta_k X_i + \varepsilon_i \qquad (1)$$

where *Production* is a function of explanatory variables focused on block groups (land, water proportion, road length, and rail length), block demographics (non-white population, urban population proportion, and median household income), and broiler production factors (distance to Salisbury and grain production), β parameter estimates, and an error term Ɛ. Salisbury, the largest broiler processor in the region, is used to account for the hub-like production where birds are processed in central locations, but the actual processing centers for each location is unknown. This model predicts the likelihood that a given block would produce any broilers, which would also account for urban blocks that would not likely have commercial poultry production based on zoning rules and population densities, but the IMR accounts for the truncated left-end tail of the distribution. Using the predicted outcomes from Equation 1, we create the IMR using Equation 2:

$$IMR = \frac{\phi(x)}{\Phi(x)} \qquad (2)$$

where the IMR is the ratio of the probability distribution function of (ϕ) to the cumulative distribution function (Φ) of the standard normal distribution (Heckman, 1979). The IMR is then used in the second stage of the analysis.

In the second stage, we only model the factors against those blocks that had any level of production to estimate the factors contributing to a block group's broiler capacity. The second stage is presented in Equation 3:

$$Broilers_i = \beta_k X_i + IMR_i + \varepsilon_i \quad \text{where } Broilers_i > 0 \qquad (3)$$

where broilers represent the count of broilers in a given block group, include additional factors focused on changes in population density, population growth, grain production changes, and income changes, with all else as previously described. All models were estimated using Stata 18. Robust standard errors were used to account for heteroskedasticity in the data. A summary of all factors included in the analysis in either stage is provided in Table 2.

RESULTS

This section presents findings from the geodatabase and the econometric analysis of Maryland's commercial broiler production between 2010 and 2024. The analysis includes spatial relationships between geographic features and broiler capacity, followed by econometric modeling to explore the factors influencing the likelihood of broiler production and broiler concentration in Census block groups with production.

Geospatial Data Relationships

Figure 3 provides a visualization of total broiler capacity across Census block groups in Maryland's Eastern Shore, with darker shades of purple representing areas with higher concentrations of broilers. Salisbury, the region's primary processing hub, is marked with a yellow star. Notably, there are few broiler M/AFOs directly within Salisbury due to its urban nature, where land use is focused on non-agricultural purposes. This urbanization factor is explored further in the econometric analysis.

An important spatial relationship uncovered in the geodatabase analysis is the negative correlation between the proportion of water within a block group and its total broiler capacity. In Figure 4, broiler capacity ("Broiler_Capacity") is mapped in orange, and the proportion of water coverage ("Prop_Water") is shaded in blue. The correlation coefficient of -0.12 indicates that the number of broilers in a block group decreases significantly as water coverage increases. This relationship is intuitive: areas with higher water coverage, typically coastal or near large bodies of water like the Chesapeake Bay, are less suitable for broiler operations due to environmental constraints and land-use restrictions. The relationship resembles a 1/x pattern or inverse relationship where even small increases in water proportion lead to sharp declines in broiler capacity, particularly in block groups with moderate to high water coverage.

Broiler Production Likelihood

The marginal effects for the broiler production likelihood model are presented in Table 3. Factors include block group geographic factors, production factors, and demographic factors. For block group factors, geophysical factors such as water coverage and physical land mass were considered, for example, for each additional percent of a block group covered in water, there was a 0.3% ($p<0.01$) decrease in the likelihood of commercial broiler production. Beyond the obvious implications of water coverage, this also may reflect block groups closer to the coast or the Chesapeake Bay area, which brings its own environmental factors that would reduce and inhibit broiler production, consistent with the geospatial analysis described above.

Regarding drivers of broiler production location decisions, processing, and access to feed is also critical. Rail length, distance to Salisbury, the largest broiler processor in the region, and grain production proportion (Grain%) are all significant factors in explaining broiler production. Rail and grain explain feed access, where feed movement may help explain the importance of rail systems and the proximity to grain sources. Feed accounts for 70-80% of the cost of raising a broiler nutritive values, and reasonable price (Mallick et al., 2020). With the growing demand for egg and poultry meat, the demand for poultry feed is also increasing. Most of the feed ingredients which are used in poultry feed are also used for human nutrition. So these major feed ingredients and cumulatively poultry feed are facing market competition with increased cost. This study proposed linear programming, thus, minimizing the distance to feed helps reduce transportation costs. The negative relationship with Salisbury, which gives a -0.2% ($p<0.01$) reduction in the likelihood of broiler production for each additional kilometer away from the processor, indicates a geographic pull centered on processing. With the average distance of 60 kilometers, the average influence on location likelihood is 12%. The geographical accessibility to processing would be important for areas with multiple processing centers that may drive the clustering of production.

As for demographics, the proportion of an urban block group is inversely related to its broiler production. For each percent higher in urban population proportion, the likelihood of the block containing broilers decreases by 0.3% ($p<0.01$). The higher the urbanization, the higher the value and competition for land and subsequent challenges to broiler-producing opportunities. This is consistent with previous studies that found fewer production facilities located in or near denser suburban areas with higher population density and a more diverse population that are not in core agricultural producing areas (Parker et al., 2018).

Factors Affecting Broiler Concentrations

Using the production model results, we now account for the censuring of Census blocks to model only the blocks with positive broiler capacity. Broiler capacity is driven predominantly by block group factors and geographic factors, specifically, water is a significant capacity factor, as shown by the likelihood model and in Figure 4. For each additional proportion of the block covered in water, there are 10.2k fewer birds ($p<0.05$), which would imply that block groups with higher water coverage producing broilers do so at smaller concentrations than those with less water coverage. A limitation of the current study is that the granular broiler data is static. An interesting extension of this result would be to study the dynamics of broiler capacity over time concerning land value, which may show the value of land increasing near desirable ocean and lakefront properties. However, given the limited data, we can observe that block groups with more water produce significantly fewer birds.

Regarding block demographics, we again show that population density in broiler-producing blocks significantly decreases broiler capacity. For each percent increase in the population density of a block group, the block's broiler capacity decreases by 3.753k broilers, which would support the general idea that production occurs in rural, less-populated areas. In the current static model, population growth was not a significant contributor to broiler capacity, but there may be longer-term effects that cannot be captured. Future modeling efforts could estimate changing demographics on production concentrations.

To emphasize the importance of proximity to urban centers with processing, distribution, and market access, it is notable that the only significant production driver of broiler capacity was the distance to Salisbury, a key hub for these essential services. For each additional kilometer away from the Salisbury processing plant, a block produces 6k fewer broilers. With an average distance of 60.6 kilometers, the production radii around the processing center could serve as a general guideline for the geographic market reach of processing capacity. A commercial broiler grower is contracted with specific processing plants. The geographical radii empirically show the gravity that processing plants have in concentrating production and could indicate continued intensification and concentration of broiler production within a feasible processing distance to Salisbury or around processing plants. For future planning purposes, this may help stakeholders and policymakers understand the agricultural and environmental implications of increased production as well as the continued demand for public infrastructure to ensure business continuity. It will also help provide some understanding for longer-term tax flow expectations.

CONCLUSION

Urbanization and land-use changes will continue to reshape the agricultural landscape, presenting new challenges for Maryland's broiler industry. The industry faces issues such as urban encroachment, environmental regulation, the need for efficient access to processing facilities, and other downstream supply chains, all of which are likely to lead to increased intensification in specific, localized areas of broiler production. By utilizing publicly available M/CAFO permits, this study mapped and analyzed broiler production at the Census block group level, providing a clearer understanding of where production is concentrated and the factors driving these decisions.

This multidisciplinary approach represents a novel advancement in agricultural data analysis by offering a more detailed and precise view of broiler production locations. Such insights are crucial for policymakers, agricultural consultants, and industry leaders navigating the evolving production landscape. The ability to evaluate factors at the block group level, rather than relying on broader county-level data, allows for a more granular understanding of the nuances affecting broiler production. This granularity is essential for decision-making, resource allocation, and environmental monitoring, particularly concerning processing accessibility and demographic changes.

The results of this study highlight the significant roles that proximity to processing centers and less-densely populated areas play in shaping production patterns. As the industry continues to adapt to land-use pressures, the insights provided by this analysis offer a framework for predicting where intensification is likely to occur. By identifying the current key drivers of production at a local level, this research provides valuable tools for anticipating shifts in the broiler industry and ensuring that Maryland's agricultural sector remains resilient and responsive to environmental and economic demands.

In creating a comprehensive geodatabase of the M/CAFO broiler population in Maryland at the Census block group level, we have enabled a more precise evaluation of production factors. This detailed analysis underscores the importance of processing centers, access to transportation infrastructure, and agrarian land availability in driving broiler production. As these factors continue to evolve, the Maryland broiler industry will need to adapt accordingly, and the results from this study provide a means for better predicting where future production intensification may occur. Moreover, the methods used in this study provide a roadmap of how GIS and agricultural economic methods could contribute to discussions of new and evolving regional siting of agricultural facilities, a timely issue given new investments that continue to be made under the USDA's Food System Transformation, introduced in the White House's recent Plan to Build Back Better framework (USDA Stories, 2022).

Future research should consider applying the methods developed here to other industries, such as beef and hog processing, as well as other commercial agricultural operations, to continue to explore how land-use pressures and industry-specific factors affect production patterns. Building on this research, future work could analyze animal health events and the effects of production regionalization, such as the spatial dynamics of highly pathogenic avian influenza and the associated regional stresses, including the operational and economic disruptions experienced by Maryland's poultry industry during the 2022 outbreak. This could provide critical insights into how intensification affects biosecurity and economic resilience.

Additionally, future studies should investigate the potential impacts of processing plant closures or shifts in consumer preferences toward non-CAFO or less-intensive poultry production systems. These shifts could require more land for production, thus, it would be essential to evaluate whether sufficient land exists within the production region, or if these changes might necessitate production movement to other geographic regions. This understanding would inform planning efforts to balance environmental sustainability, economic viability, and consumer demand.

Policymakers and conservation groups can play a pivotal role in supporting balanced changes by leveraging zoning regulations, providing funding for sustainable farming practices, and offering field support to assist farmers in adapting to new production models or regulations. These efforts could help ensure that the agricultural landscape evolves in a way that is both economically and environmentally sustainable, fostering resilience in Maryland's agricultural sector while addressing the challenges posed by urbanization and land-use changes.

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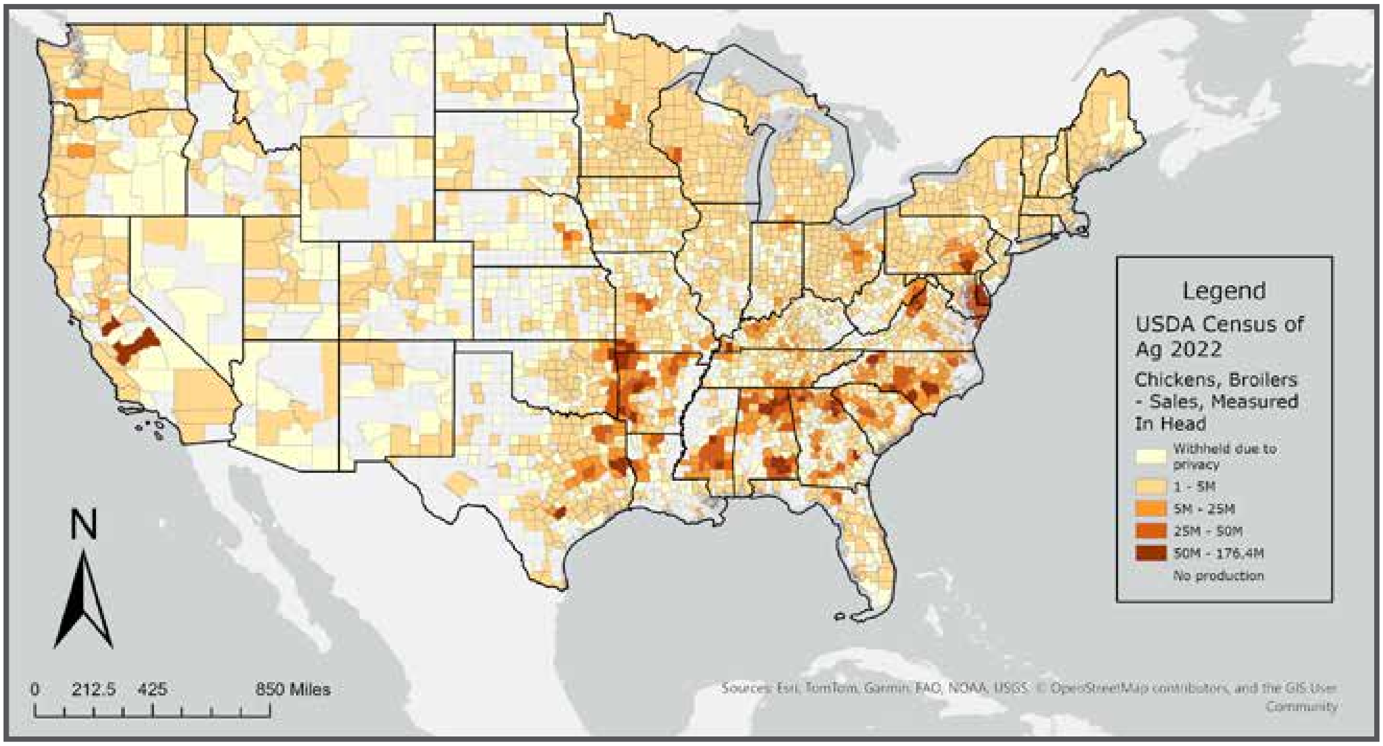

Figure 1. County-level distribution of broiler chicken sales in the United States, measured in head, based on data from the USDA's 2022 Census of Agriculture

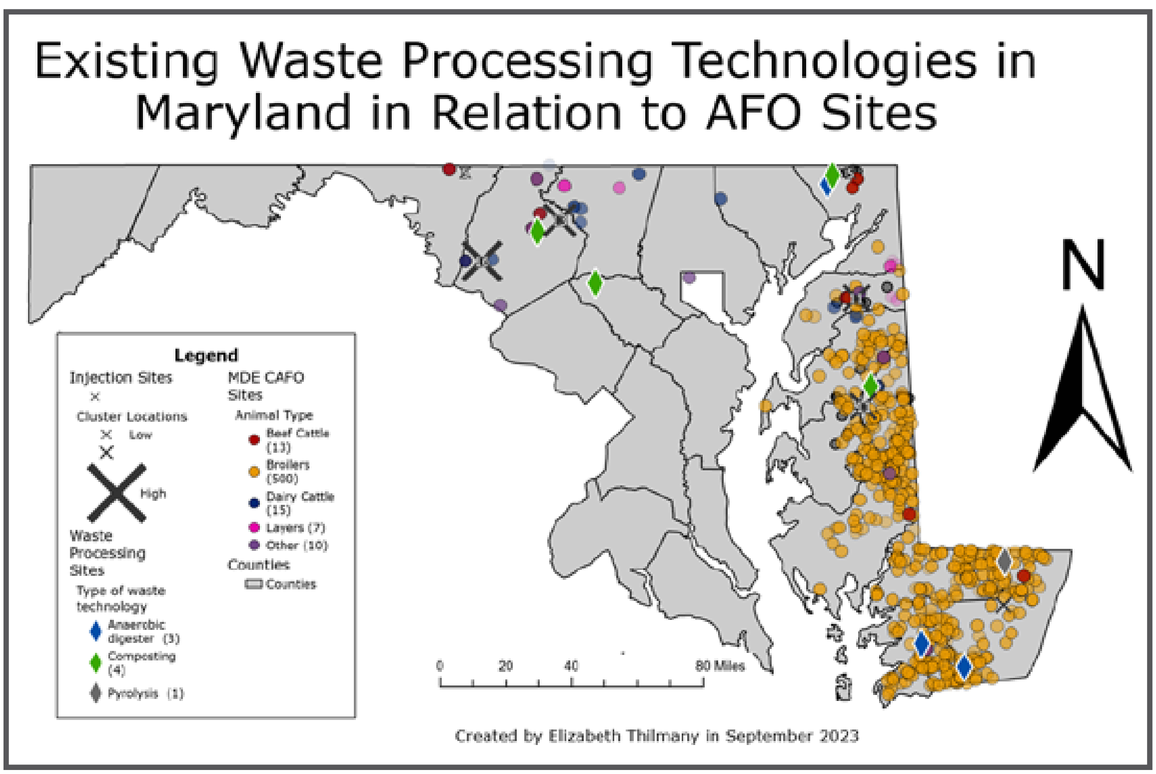

Figure 2. Distribution of active broiler M/CAFOs and animal waste technology sites in Maryland in 2023 from "Maryland Animal Waste Technology Assessment and Strategy Planning Report" (Lansing et al., 2023)

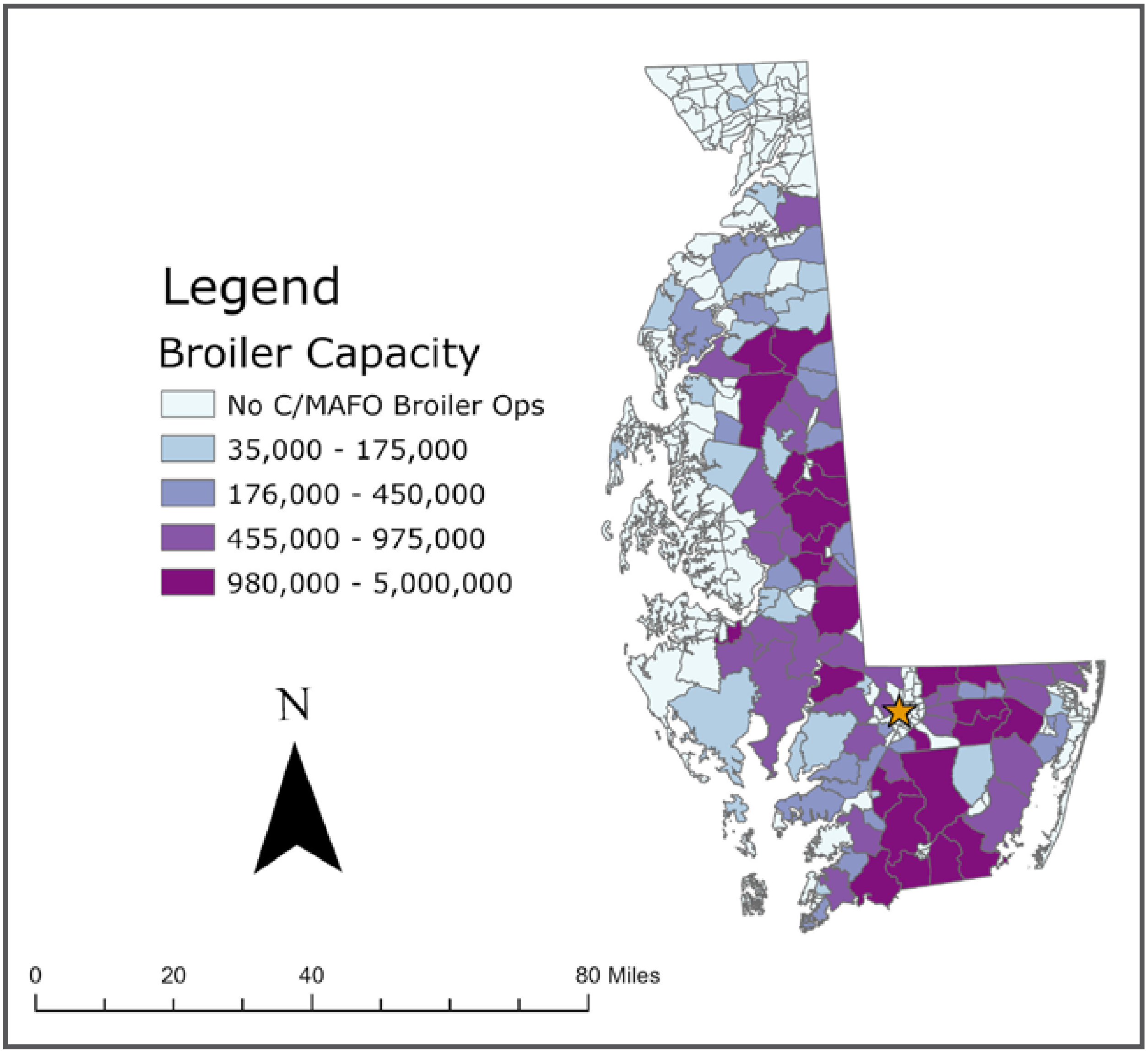

Figure 3. 2024 M/CAFO broiler capacity by Census block group in Maryland in relation to Salisbury, Maryland

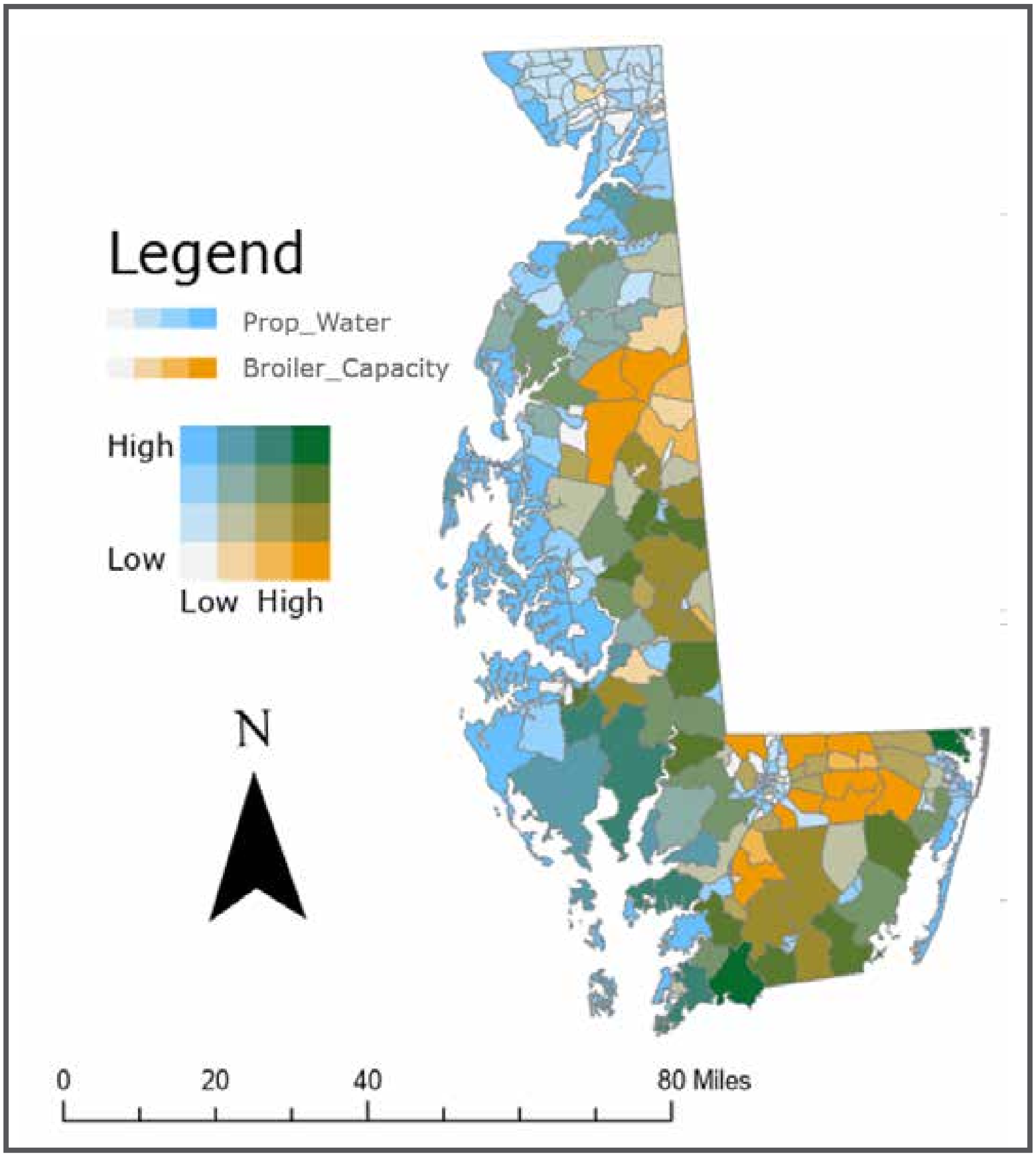

Figure 4. Relationship between broiler capacity and proportion of water in block groups

Table 1. Data Sources and Use in Study				
Data Source	**Description**	**Variables Used**	**Purpose in Study**	**Method of Acquisition**
Maryland Department of the Environment (MDE) permits	Site-specific permitting data for M/CAFOs that discharge pollutants into state waters	Facility location, broiler capacity, permit type	To determine broiler capacity at each block group	Accessed via Maryland Public Information Act
U.S. Census Bureau – 2010 Population Data	Population data from the 2010 U.S. Census at the block group level	Total population, racial demographics	To analyze population demographics in relation to AFOs	Publicly available U.S. Census files
U.S. Census Bureau – 2020 Population Data	Population data from the 2020 U.S. Census at the block group level	Total population, racial demographics	To analyze changes in population demographics between 2010 and 2020	Publicly available U.S. Census files
NHGIS Crosswalk Data (2010–2020)	Crosswalk data linking 2010 and 2020 census block group boundaries for comparison	Interpolation weights, block group identifiers	To align population data across census years and adjust for boundary changes	National Historical Geographic Information System (NHGIS)
NASS Cropscape – Cropland Data Layer	Raster dataset providing detailed crop classifications	Corn and soybean acreage (2010, 2020)	To estimate potential poultry feed sources in each block group	Accessed via USDA NASS Cropscape
FSIS (Food Safety and Inspection Service)	Locations of poultry processing facilities regulated by FSIS in Maryland	Facility locations, distances from block groups	To evaluate proximity of block groups to poultry processing facilities	Publicly available FSIS data, analyzed in ArcGIS
U.S. Census Bureau – 2013 Income Data	Income data from 2013 at the Census block group level	Median household income	To assess income levels in relation to AFO distribution	Publicly available U.S. Census files
Transportation Data – Railroads	Polyline data on freight railroads in Maryland	Total length of railroads in each block group	To assess access to rail transportation for poultry and feed logistics	Maryland Department of Transportation
Transportation Data – Highways	Polyline data on major highways, including interstates, MD routes, and U.S. routes	Total length of highways in each block group	To assess access to highways for poultry and feed logistics	Maryland Department of Transportation

Table 2. Data Summary for Maryland Census Block 2010–2020

Variable	Description	N	Mean	SD	Min	Max
Broilers	Thousands of Birds	96	738.2	875.1	37.8	4,791.2
Land	100k of Sq Meters	334	251.3	363.2	3.1	2,834
Water Proportion	Proportion	334	12.7	19.4	3.0	2,834
Road Length	Kilometers	334	1.2	1.9	0.0	9.6
Rail Length	Kilometers	334	1.2	2.4	0.0	14.7
Distance to Salisbury	Kilometers	334	60.6	47.8	0.0	154.7
Non-White Population %	% of Total Population	334	21.4	19.4	1.1	96.7
Urban Population %	% of Total Population	334	38.8	43.8	0.0	100.0
Median Household Income	Thou. Dollars	334	60.9	22.9	13.3	140.9
Household Income Growth 2010-2020	% Growth	321	18.5	40.8	-60.1	252.0
Population Density 2010	Capita per Mil. Sq. Meters	334	399.2	572.9	0.0	3,050.9
Population Growth 2010-20	% Growth	334	2.4	15.5	-30.4	155.9
Grain %, 2010	% of Total Grain Acres	334	0.9	1.4	0.0	8.7
Grain Acres 2020	Thousands of Acres	334	8.3	13.2	0.0	93.3
Grain Acre Growth 2010-20	% Growth	325	-33.2	41.3	-100.0	366.7

Table 3. Results for Two-Stage Modeling for Maryland Broiler Production 2010–2020

	Production Model Marginal Effects		Broiler Model	
Land	0.010	(0.000)	0.027	(0.205)
Water Proportion	-0.003***	(0.001)	-10.248**	(5.108)
Road Length	-0.003	(0.009)	-56.071	(42.612)
Rail Length	0.015**	(0.006)	-18.428	(37.623)
Distance to Salisbury	-0.002***	(0.000)	-6.009***	(1.803)
Non-White Population %	-0.002*	(0.001)	-7.064	(6.489)
Population Growth 2010-2020			4.486	(10.246)
Grain Acre Growth 2010-2020			-6.227	(7.825)
Household Income Growth 2010-2020			-2.991	(2.403)
Population Density 2010			-3.753*	(1.941)
Grain Acres 2020			15.556	(9.920)
Median Household Income 2013	-0.001	(0.001)	-3.694	(5.651)
Urban Population %	-0.003***	(0.000)		
Grain %, 2010	0.047**	(0.022)		
IMR			-1.345	(1.479)
Constant	1.145*	(0.633)	1,424.353***	(454.723)
Observations	334		96	
Pseudo R2/R2	0.603		0.247	

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Are Ranchers Interested in Joining the Carbon Market? Survey Says: Maybe



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Abstract

The carbon market offers an opportunity for ranchers to receive compensation for engaging in stewardship practices that sequester greenhouse gases. We present results from a survey administered in January 2024 of 504 ranchers across 10 Great Plains and Front Range states exploring their willingness to join the carbon market, and their reasons for non-participation. We found that 55% of respondents are interested in joining a grassland carbon market program. Top non-participation reasons include concerns about long-term contracts, payment amounts, and having a conservation easement to be eligible. Private carbon markets and future federal programs should consider ranchers' preferences for enrollment if they want to encourage participation.

INTRODUCTION

The voluntary carbon market (hereafter "carbon market") presents an emerging opportunity for producers to generate an additional stream of income while practicing land stewardship. Despite the potential for carbon sequestration on grazing lands (i.e., rangelands and grasslands suitable predominantly for livestock grazing, hereafter "grasslands"; Stanley et al., 2024), recent research primarily has focused on crop producer preferences related to this emerging market (Derner and Schuman, 2007; Kalady et al., 2024). Since the collapse of the Chicago Climate Exchange (CCX) in 2011, the carbon market has evolved to include a wider range of carbon companies and programs available for ranchers as well as farmers. To participate in the carbon market, ranchers must improve their land management practices to sequester additional carbon dioxide (CO_2) from the atmosphere. Such practices include rotational grazing, reseeding, applying fertilizer, or enrolling in a conservation easement, all of which typically results in optimizing plant growth and consequently affecting carbon sequestration (Jordon et al., 2022; Leghari et al., 2016). The CO_2 captured in the soil because of these improved practices can then be sold as carbon credits (hereafter "credits"). One credit is equal to the sequestration of one metric ton of CO_2 equivalents in soil or the prevention of one metric ton of CO_2 from being released. The average price of a carbon credit in the agricultural sector sold for $6.43/credit in 2023 (Ecosystem Marketplace, 2023), though prices are influenced by market supply and demand. These credits can be purchased by individuals and companies to offset the emissions produced from their activities. There are 170 different types of credits (e.g., those related to forestry, methane capture, waste management, etc.) that can be generated (Ecosystem Marketplace, 2022). Our research focuses specifically on credits derived from ranchers' livestock management practices on grasslands.

We present survey data exploring ranchers' willingness to participate in the carbon market who are located in the 10 states in the Great Plains and Front Range of the United States. This research is the first to explore ranchers' preferences for contemporary carbon programs that involve livestock management on such lands used for grazing.

BACKGROUND

Ranchers can work with numerous carbon companies (referred to as "project developers") to develop a carbon project on the property they own or manage. Carbon company programs vary in contract length, payment amounts and frequencies, management change requirements, and enrollment rates, but they adhere to the fundamental rules established by the registries. These registries develop the methodologies or protocols that define the requirements that projects must meet to generate and sell credits (Brammer and Bennett, 2022). The three prominent registries with grassland protocols relevant to ranchers are American Carbon Registry (ACR), Climate Action Reserve (CAR), and Verra. Grassland protocols require carbon projects to either collect soil samples and measure soil carbon every five years or enroll the property into a conservation easement. Ranchers who participate in the carbon market sign a contract with a carbon company, committing to follow the contract's guidelines. The carbon company manages the project, maintains the necessary paperwork and records, and serves as the liaison with the registries (Brammer and Bennett, 2022). The carbon company typically covers the costs associated with developing the carbon project (i.e., market entry fees, infrastructure improvements, soil sampling, etc.) and assumes the financial risk by purchasing the rights to the credits. Ranchers can "shop around" between different carbon companies (e.g., Agoro, Ducks Unlimited, Grassroots, Kateri, Native) to select a program that best aligns with their goals (Nimlos, Gergeni, and Scasta, 2025).

Previous research examines potential costs and profitability for grassland producers participating in carbon markets using CCX prices (Ritten, Bastian, and Rashford, 2012; Campbell et al., 2004), but literature examining ranchers' current preferences for carbon programs on grasslands is limited. However, research in the broader carbon market suggests that while crop farmers are generally aware of carbon markets and are interested in selling credits, they often face uncertainty regarding information, policies, and associated costs (Han and Niles, 2023). Other research suggests that farmers have a low willingness to join the carbon market, with carbon program design and farmer characteristics contributing to the reluctance (Kolady et al. 2024). Crop carbon markets often require farmers to reduce tilling or plant cover crops, whereas grassland carbon markets typically involve improving grazing (i.e., increasing pasture rest periods). Thereby, willingness to engage in the carbon market may differ between row crop farmers and livestock ranchers, highlighting the importance of exploring ranchers' preferences separately from crop farmers. Lastly, research indicates producer and property characteristics (e.g., age, gender, property size, etc.) impact willingness to enter into forest carbon contracts, with younger, female respondents operating on larger sized properties being more willing (Sharma and Kreye, 2022; K.A. Miller, Snyder, and Kilgore, 2012).

Understanding ranchers' preferences for the carbon market informs critical design elements of both current programs in private markets and potential future government initiatives. In 2023, the United States Department of Agriculture (USDA) invested $8 million to support and expand the measurement and monitoring of soil carbon on working agricultural lands to assess how climate-smart practices impact carbon sequestration.[1] This investment suggests that federally run voluntary carbon programs may emerge in the future. Thus, this research may offer valuable insights for tailoring such programs to better meet ranchers' needs while supporting agricultural production in the U.S.

METHODS

Survey Methods

We obtained our data for this research by administering a modified Dillman design survey using a hybrid delivery approach (mixture of online and paper mail survey delivery; Dillman, Smyth, and Christian, 2014). DTN services (www.dtn.com) provided a randomly selected list of eligible landowners or land managers that included their physical addresses and emails. We initially emailed participants to inform them that a survey would be arriving in the mail. We then mailed the survey to participants' physical addresses and sent two reminder emails at two-week intervals to encourage completion. Respondents also had the option to complete the survey online via *Qualtrics*. We received 504 valid surveys (n = 504) and 100 invalid surveys due to return to sender, deceased respondents, or respondents who had moved away. Given our initial sample size of 3,500 ranchers, our response rate was 15%.

We mailed our survey to 3,500 ranchers in January 2024, targeting ranchers who own or operate on 200 or more acres of grasslands, rangelands, or shrublands in 10 states within the Great Plains and Front Range, including Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wyoming. We distributed an equal number of surveys to each state in attempt to ensure representative coverage of ranchers from our target population.

The survey first asked respondents to select all the enterprises they operated on their land, including cattle and calves, hay, hogs and pigs, sheep or goats, horses, ponies, mules, burros, or donkeys, poultry or eggs, non-hay crop production, or other (the survey is available upon request from the corresponding author). We also inquired about the state where the majority of their property was located, property size, gender, and age range (18-24, 25-44, 45-64, 65-84, or 85 or above). We proceeded to ask respondents to indicate whether they had heard of the carbon market prior to the survey (yes, no, somewhat).

Next, we provided respondents with the following preamble: "Imagine you have been contacted by a carbon project developer. They have presented you with an opportunity to participate in a grassland carbon project and have offered you a contract for three different programs that you could enroll in. Additionally, the project developer has successfully secured a buyer who is interested in purchasing the carbon credits generated by your participation in the program. This means that your management efforts will have a tangible value in the market. Below, you will find the characteristics of three different grassland carbon programs." We then presented respondents with three carbon programs that varied in their characteristics, including the requirement to enroll in a conservation easement, soil testing requirements, contract length, and an established record of the program selling carbon credits. These programs represented existing programs in the carbon market under American Carbon Registry's *Avoided Conversion of Grasslands and Shrublands to Crop Production* protocol, Climate Action Reserve's U.S. Grassland Protocol, and Verra's VM0026 *Methodology for Sustainable Grassland Management.*

We then asked respondents whether they would enroll in any of the three programs. We posed this question four times with varying payment amounts based on current market levels to gauge overall willingness to participate in any of the programs.

Finally, we asked respondents who were not interested in enrolling in one or all of the carbon programs to select the reasons for their reluctance. For institutional research compliance, this study was reviewed by the University of Wyoming Institutional Review Board (IRB) and determined to be exempt from further federal regulations on September 26, 2023.

Data Analysis

We generated a binary response variable for our initial analysis, coded as "1" if ranchers selected one of the three programs or "0" if they opted out in all four questions. We calculated the proportion of ranchers willing to join the carbon market and the Wald 95% confidence intervals for this proportion. We used chi-square tests of independence to examine relationships between respondents' age, awareness of the carbon market (yes or somewhat = 1, no = 0), gender (male = 1, female = 0), and location with their willingness to participate in the carbon market. Chi-square tests of independence are useful for determining whether two categorical variables in a sample are independent or associated with each other (Franke, Ho, and Christie, 2012). We ensured the chi-square tests met the assumptions of categorical and mutually exclusive variables, independent observations from a random sample, and expected cell counts of five or more in the contingency tables (Naioti and Mudrak, 2022). We calculated Adjusted Pearson residuals to identify which categories contributed significantly to the chi-square test, with residuals having absolute values greater than the critical value of 1.96 considered significant at the $\alpha = 0.05$ level (Naioti and Mudrak, 2022).

We conducted a multiple logistic regression to assess whether operation type, property size, or respondent location could predict willingness to join the carbon market, given past research regarding willingness to enter forest carbon contracts (Sharma and Kreye, 2022). We created binary variables for each operation type and coded them as "1" if respondents engaged in that enterprise or "0" if they did not. We treated privately owned and leased acres as continuous variables, then we set location as a factor variable, with 10 levels corresponding to respondents' states and New Mexico set as the reference level. We also examined potential issues of multicollinearity via variance inflation factors (VIFs; Shrestha, 2020). We utilized R software for all analyses and considered p-values less than 0.05 as statistically significant.

RESULTS

Demographics

Presented in order from greatest to least, we received 68 surveys from Wyoming (14.11%), 64 from Colorado (13.28%), 58 from Kansas (12.03%), 56 from Montana (11.62%), 54 from North Dakota (11.20%), 53 from Nebraska (11.00%), 49 from South Dakota (10.17%), 41 from Oklahoma (8.51%), 33 from Texas (6.85%), and 6 from New Mexico (1.24%; Table 1; Figure 1). Twenty-two respondents did not indicate their location. The largest share of respondents raised cattle and calves (n = 431, 89.42%), were male (n = 402; 83.75%), and between 65 and 84 years old (n = 282, 57.79%; Table 1). On average, respondents operated on 3,132 leased acres (median = 988; range = 20-100,000) and 2,297 deeded acres (median = 1,000; range = 6-28,000; Table 2). Our survey included over 720,000 leased acres and 957,000 deeded acres, encompassing over 1.6 million acres.

Willingness to Join the Carbon Market

The majority of respondents were aware, or somewhat aware, of the carbon market prior to the survey (n = 286; 57.78%; Table 3). Fifty-five percent of respondents indicated they would participate in one of the presented carbon programs (n = 262; 54.93%) rather than opting out of all of them (n = 215; 45.07%; Table 4). Statistically, the proportion of ranchers interested in joining the market falls between 50% and 59% (95% Confidence Interval). It should be noted that we cannot assess whether respondents' stated intentions may differ from their actual behavior if given the opportunity to participate in the carbon market. Colorado (n = 41), Wyoming (n = 33), and Kansas (n = 30) had the most respondents select a carbon program (Figure 2). The states with the largest proportion of respondents willing to participate in the market were Colorado (66%), Texas (58%), Nebraska (57%), and North Dakota (57%; Figure 3).

Barriers to Enrollment

Respondents who opted out of one or all of the presented programs indicated that they did not want to enter into a long-term contractual agreement (n = 217; 43.06%), the financial compensation was not high enough (n = 189; 37.50%), they did not want to enroll their land in a conservation easement (n = 138; 27.38%), they do not trust the carbon market (n = 118; 23.41%), they do not want to sell carbon credits to polluting companies (n = 82; 16.27), they do not want to change their management practices (n = 59; 11.71%), another reason (n = 47; 9.33%), or the costs to join the market are too high (n = 39; 7.74%; Table 5; Figure 4).

There was a significant relationship between willingness to join the market and age, but not with awareness of the market, gender, or location (Table S1 in the supplementary section). Given that 84% of respondents were male, it is not surprising that there was no significant relationship between willingness to participate and gender. These results might differ if the survey had a higher proportion of female respondents, as research suggests that women are generally more willing to engage in pro-environmental behaviors (Casaló and Escario, 2018; Casaló, Escario, and Rodriguez-Sanchez, 2019; Briscoe et al., 2019). Ranchers around 55 years old were more likely to enroll in a carbon program than those around 75 years old (Table S2 in the supplementary section). Survey responses were low among respondents aged 18-24 (0%), 25-44 (5%), and 85 or older (5%), so it is not surprising that no significant relationship was observed from those age ranges. Our regression results indicate respondents with haying operations and more privately owned acres were more likely to enroll in a carbon program, while those conducting non-hay crop production were less likely (Table S3 in the supplementary section).

It is important to note that females and ranchers in New Mexico were underrepresented in this survey. While females make up 36% of producers in the U.S. (USDA, 2022), only 16% of our survey respondents were female. Additionally, only 1.24% of respondents were located in New Mexico. Thus, conclusions about females and ranchers in New Mexico are limited. Additionally, the mean age of survey respondents was 66 years, which is slightly higher than the average age of 58 years for producers in the U.S. (USDA, 2022). Future research efforts should include a larger and more diverse sample of ranchers from a broader range of states.

DISCUSSION AND CONCLUSION

We've presented a first look at survey data assessing ranchers' willingness to participate in the carbon market and explored reasons why some ranchers are hesitant. Our results reveal that 55% of respondents were interested in joining the carbon market. This willingness is higher compared to findings from studies on crop and forest producers' willingness to participate in the carbon market (Canales, Bergtold, and Williams, 2023; Markowski-Lindsay et al., 2011; K.A. Miller, Snyder, and Kilgore, 2012). Our results also indicate that younger ranchers are more likely to enroll in the carbon market compared to older ranchers, a trend observed in studies on landowners' willingness to join conservation programs (Farmer et al., 2017;

Langpap, 2004). Additionally, ranchers with larger properties were more willing to participate in the carbon market, a finding also consistent with other research on landowners' willingness to join the carbon market (Dickinson et al., 2012; K.A. Miller, Snyder, and Kilgore 2012). This result is understandable because larger property sizes often offer greater revenues from the carbon market, so landowners with smaller properties may consider aggregating with neighboring landowners to enhance the project's appeal (Kerchner and Keeton, 2015).

Interestingly, we found that ranchers who hayed were more likely to participate in the carbon market, which is a new finding in the literature. This is notable because some carbon programs incentivize ranchers to apply nitrogen fertilizer and reseed, practices that may align well with haying. On the contrary, ranchers who also conducted non-hay production were less willing to join the market, which is consistent with other literature stating farmers have low willingness to participate in carbon markets (Canales, Bergtold, and Williams, 2023). A portion of respondents had never heard of the carbon market before this survey, suggesting that educating ranchers about the opportunities available to them within the carbon market will be necessary. Informing ranchers about the additional ecological and societal benefits of improving management through a carbon program could also be important for promoting the adoption of conservation practices (Canales, Bergtold, and Williams, 2023).

Respondents who chose to opt out of one or all programs noted concerns about long contract lengths, low payments, and requirements for enrolling in a conservation easement. These concerns are consistent with findings from existing literature that identify long contracts and low payments as significant barriers to crop and forest landowners enrolling in the carbon market (Markowski-Lindsay et al., 2011; Sharma and Kreye, 2022; K.A. Miller, Snyder, and Kilgore, 2012). The current compensation offered to landowners for participating in the carbon market is likely insufficient, both in terms of encouraging widespread enrollment and in the benefits being provided to society (e.g., the provision of ecosystem services, wildlife habitat, open spaces, etc.; Thompson et al., 2022). This concern remains consistent with past research regarding potential profitability for grassland owners (Ritten, Bastian, and Rashford, 2012). Carbon programs that require ranchers to enroll in a conservation easement are relatively new, so there is limited literature on their preferences for such programs. However, existing research suggests reluctance among landowners to engage in conservation easements due to concerns about losing managerial flexibility and control, permitting public access, and low financial incentives (A.D. Miller et al., 2010; Bastian et al., 2017).

Ranchers who are not interested in joining the carbon market can still participate in federal and state conservation cost-share programs, which have been the main conduits of promoting the adoption of conservation practices in the U.S. (Canales, Bergtold, and Williams, 2023). Government voluntary programs like the Conservation Reserve Program (CRP) may have higher payouts than agricultural carbon markets. For example, the average rental payment under the CRP was $74/acre in 2023, whereas the average price of a carbon credit was $6.51 in the agricultural sector, with U.S. rangelands generating approximately 0.30-0.67 carbon credits per acre (Conservation Reserve Program, 2023; Ecosystem Marketplace, 2024; Ritten, Bastian, and Rashford, 2012). Furthermore, research suggests that farmers generally prefer federally run conservation programs (e.g., CSP, EQIP) over market-based carbon programs (Canales, Bergtold, and Williams, 2023; Thompson et al., 2022). This may be due to limited awareness of carbon market programs, the lack of policies supporting the creation of the carbon market, and negative experiences with previous carbon markets. This research, along with other reported results, highlights the need for diverse types of contracts and payment levels to boost participation in carbon programs (Sharma and Kreye, 2022). Moreover, these results also suggest an important role for educational information aimed at agricultural producers in general to help them make informed decisions.

Future research should explore ranchers' preferences for individual carbon programs. Examining payment characteristic preferences such as whether ranchers prefer annual payments or lump sums every five years, and whether they prefer programs that require conservation easements or demonstrating soil carbon accumulation to receive payments will also be informative. As societal pressure to reduce greenhouse gas emissions grows, there will likely be continued opportunities for ranchers to receive compensation for capturing greenhouse gases on their land. Therefore, facilitating education to increase awareness of existing programs and opportunities, knowing their willingness to join the market, understanding their preferences for carbon program design, and addressing the factors impacting these decisions will all be critical.

FOOTNOTES

1 https://www.nrcs.usda.gov/resources/data-and-reports/soil-carbon-monitoring-agreements-fiscal-year-2023

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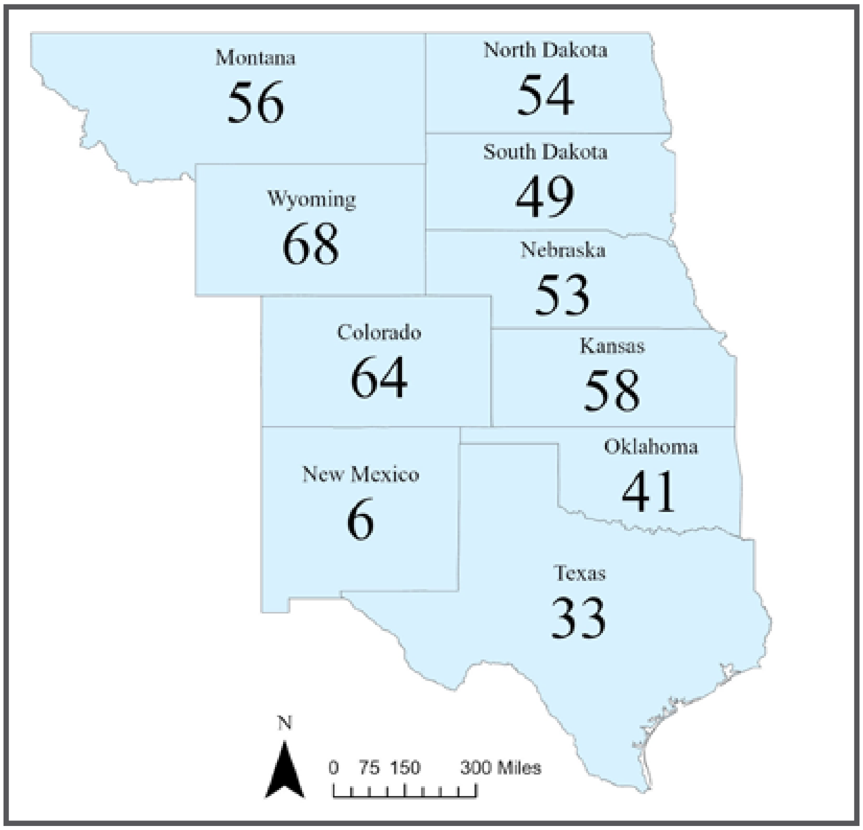


Figure 1. Number of surveys collected from the target population (n = 482); 22 respondents did not indicate their location in the survey

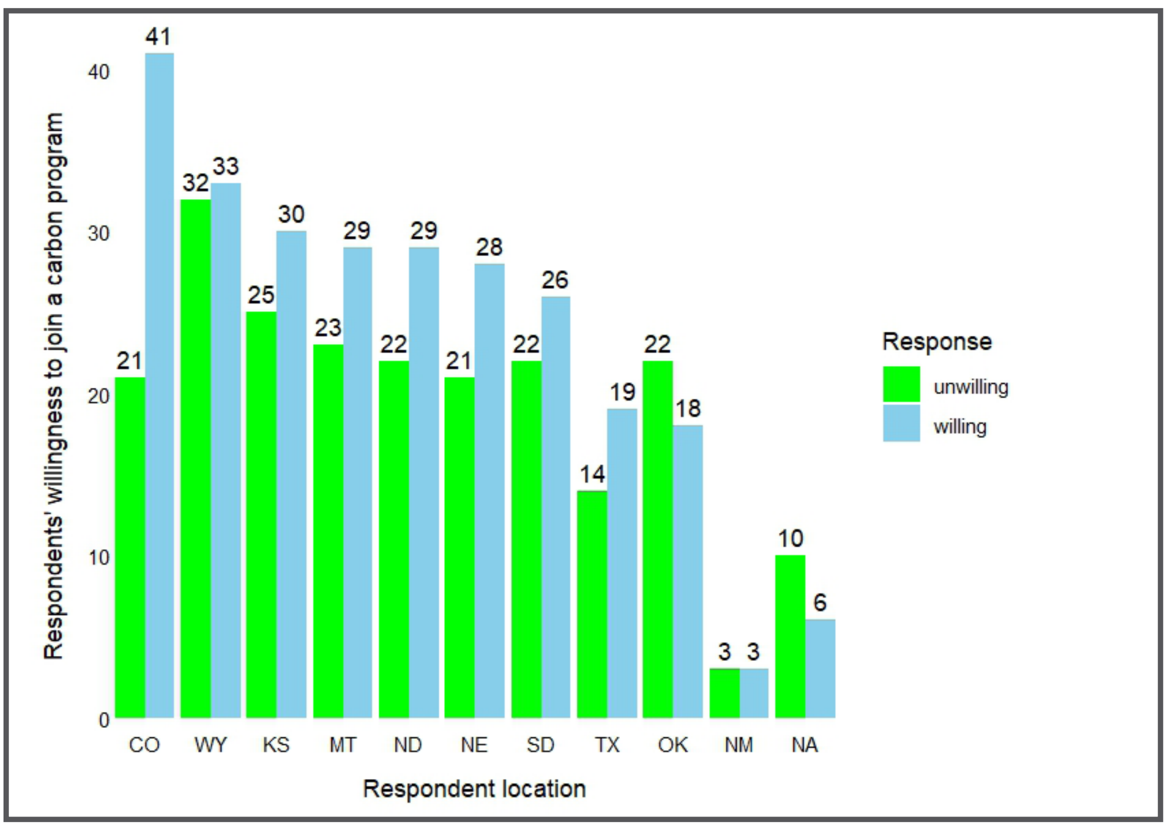


Figure 2. Respondents' willingness to join a carbon program by location (n = 477); note: NA represents respondents who did not indicate their location

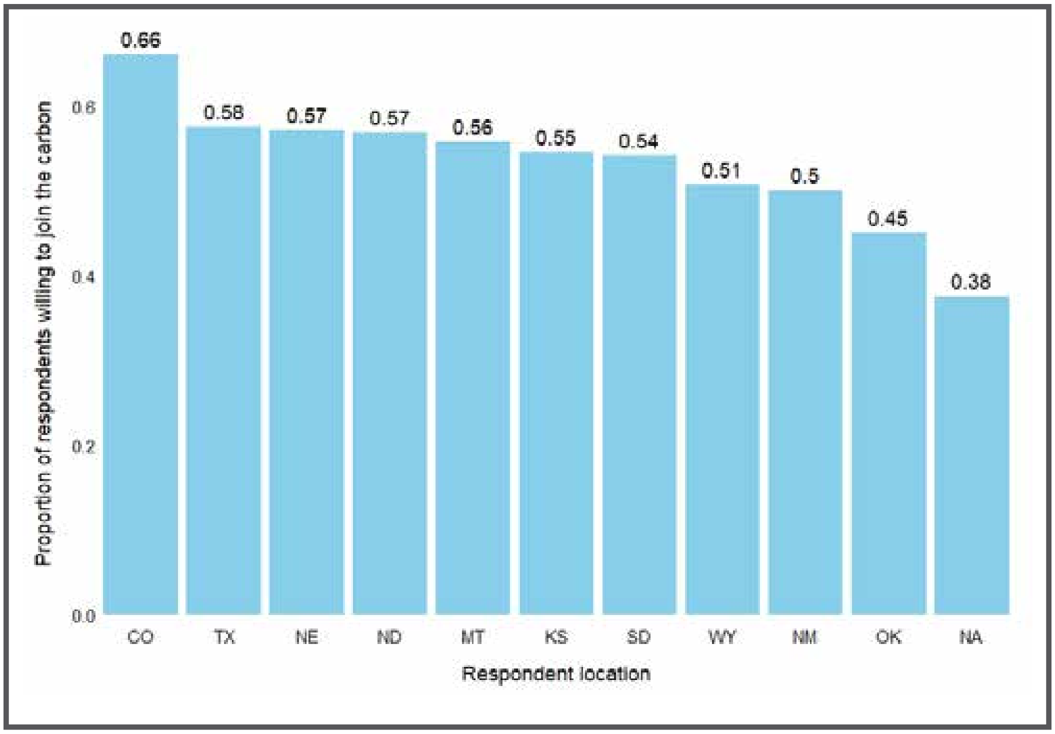


Figure 3. The proportion of respondents willing to join the carbon market by location (n = 477); note: NA represents respondents who did not indicate their location

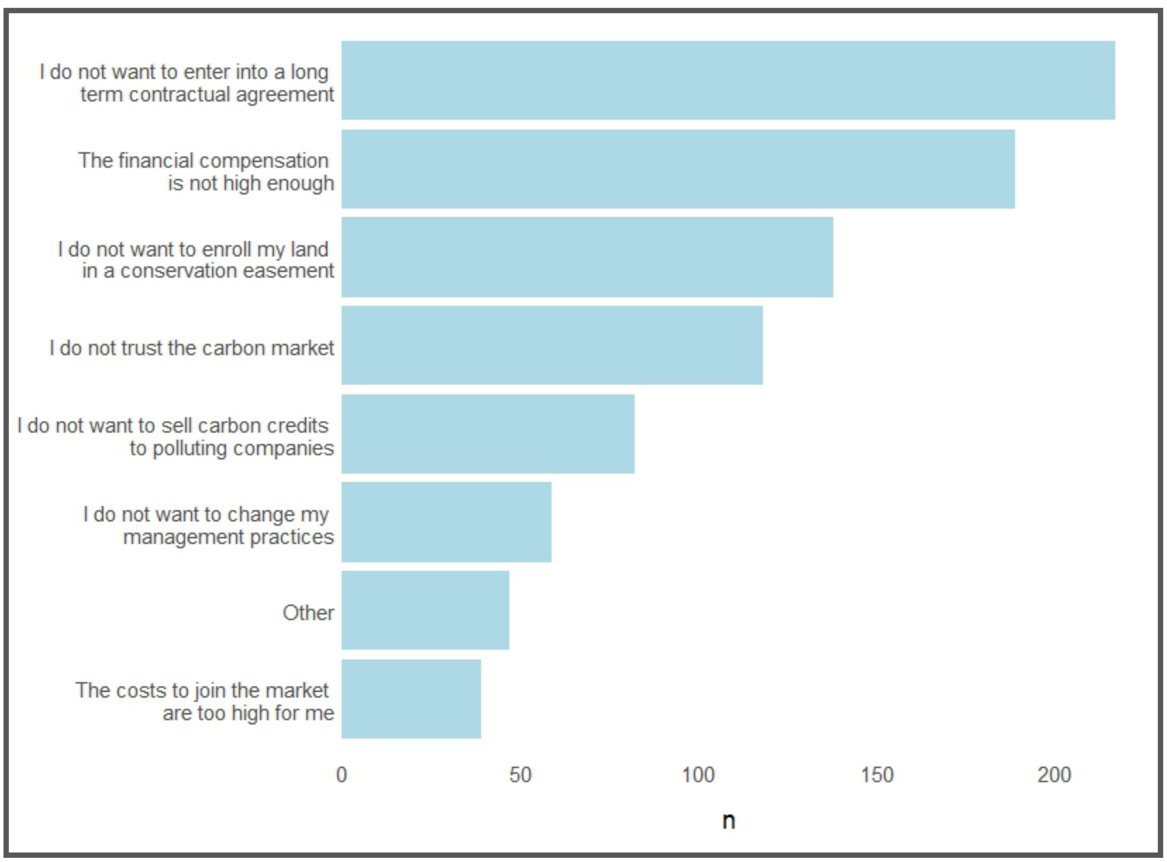


Figure 4. Reasons respondents were unwilling to join a carbon program

Table 1. Survey Respondent Characteristics (*n* = 504)		
	No.	**%**
Operation type		
Cattle and calves	431	89.42
Hay	283	58.71
Non-hay crop production	134	27.80
Horses, ponies, mules, burros, or donkeys	94	19.50
Other	44	9.13
Sheep or goats	29	6.02
Poultry or eggs	28	5.81
Hogs and pigs	6	1.24
Location		
Colorado	64	13.28
Kansas	58	12.03
Montana	56	11.62
Nebraska	53	11.00
New Mexico	6	1.24
North Dakota	54	11.20
Oklahoma	41	8.51
South Dakota	49	10.17
Texas	33	6.85
Wyoming	68	14.11
Gender		
Male	402	83.75
Female	78	16.25
Age		
18-24	0	0
25-44	25	5.12
45-64	159	32.58
65-84	282	57.79
85 or above	22	4.51

Table 2. Property Sizes and Ownership Types of Survey Respondents (*n* = 504)					
	Mean	**Median**	**Minimum**	**Maximum**	**Sum**
Leased acres	3,132	988	20	100,000	720,316
Deeded acres	2,297	1,000	6	28,000	957,684

Table 3. Respondents' Awareness of the Voluntary Carbon Market Prior to the Survey (*n* = 495)		
	No.	**%**
Yes	187	37.78
No	209	42.22
Somewhat	99	20.00

Table 4. Respondents' Interest in Participating in a Grassland Carbon Program (*n* = 477)*		
	No.	**%**
Selected one of the three programs	262	54.93
Would not be interested in joining any of the carbon programs	215	45.07

* Wald confidence interval for willingness to join the market: (0.50, 0.59)

Table 5. Reasons Respondents Were not Interested in Joining a Carbon Program		
	No.	**%**
I do not want to enter into a long-term contractual agreement	217	43.06
The financial compensation is not high enough	189	37.50
I do not want to enroll my land in a conservation easement	138	27.38
I do not trust the carbon market	118	23.41
I do not want to sell carbon credits to polluting companies	82	16.27
I do not want to change my management practices	59	11.71
Other	47	9.33
The costs to join the market are too high for me	39	7.74

SUPPLEMENTARY MATERIALS

Table S1. Results from the Chi-Square Tests for Variable Independence

	X^2	df	p-value
Age	10.63	3	0.014*
Awareness of market prior to survey	1.96	2	0.38
Gender	0.10	1	0.75
State[a]	5.42	8	0.71

[a]New Mexico was dropped from the analysis due to lack of respondents from this state.
*p<0.05.

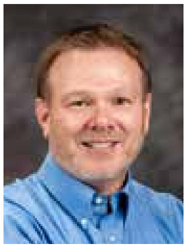
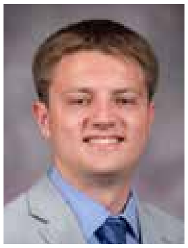
Table S2. The Adjusted Pearson Residuals Run Post Hoc of the Chi-Square Test of Independence between Respondent Willingness to Enroll in a Carbon Program and Age

Age Category	Chose not to Select a Carbon program	Selected a Carbon Program
34.5	0.83	-0.83
54.5	-3.06	3.06
74.5	1.96	-1.96
85 or above	1.49	-1.49

Table S3. Multiple Logistic Regression Model to Assess if Enterprise Type, Property Size and Type, and Respondent Location Predict Willingness to Participate in the Carbon Market					
Variable	**Coefficient (β)**	**Standard Error**	**z-value**	**p-value**	**VIF[a]**
Intercept	-0.82	0.96	-0.85	0.39	
Cattle and calves	-0.24	0.31	-0.77	0.44	1.12
Hay	0.51	0.22	2.36	0.018*	1.15
Hogs and pigs	0. 42	1.01	0.42	0.67	1.056
Sheep or goats	-0.031	0.045	-0.068	0.95	1.093
Horses, ponies, mules, burros, or donkeys	0.14	0.26	0.55	0.58	1.075
Poultry or eggs	0.87	0.49	1.81	0.070	1.097
Non-hay crop production	-0.47	0.23	-2.03	0.042*	1.10
Other	0.19	0.36	0.052	0.96	1.076
Private acres	0.00011	0.000038	2.81	0.0049*	1.12
Leased acres	-0.000022	0.000017	-1.34	0.18	1.08
Colorado	1.23	0.95	1.29	0.20	1.03
Kansas	0.88	0.96	0.91	0.36	1.03
Montana	0.59	0.95	0.63	0.53	1.03
Nebraska	0.81	0.95	0.85	0.39	1.03
North Dakota	0.81	0.96	0.84	0.40	1.03
Oklahoma	0.47	0.97	0.49	0.63	1.03
South Dakota	0.60	0.96	0.63	0.53	1.03
Texas	0.94	0.98	0.96	0.34	1.03
Wyoming	0.44	0.94	0.46	0.64	1.03

[a] Variance inflation factor for assessing multicollinearity; the calculated VIF values were close to one, implying we had no issues with multicollinearity (Shrestha, 2020).
[b] New Mexico was set as the reference level for respondents' location.
*p<0.05.

Do Newer Model Planters Improve Corn Yields?


By Joe Parcell, Weston Guetterman, and Alice Roach

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Abstract

Using a unique subset of National Corn Growers Association yield contest data, we evaluated whether newer planter models lead to higher corn yields in situations where producers follow high-yield management practices. Results indicated that using new-generation planters increased yield by up to six bushels per acre relative to recent planter models. Although a six-bushel yield increase is significant for farms planting several thousand acres, small-acreage farms will not generate a return on the yield increase alone to justify the cost of trading in an earlier generation planter. Farms with less acreage may consider precision upgrade kits to eliminate some of the yield drag associated with owning an earlier planter model. A research limitation is that planter upgrades are unknown. We avoided a "brand conundrum" by grouping planter models into year ranges according to when a model was first introduced.

INTRODUCTION

Recent years have brought record crop yields, record-high commodity prices followed by much lower commodity prices, and record-high farm incomes followed by significant year-over-year drops in national and state-level farm income (Rural and Farm Finance Policy Analysis Center, 2024). In recent years, farms bought equipment despite new and used farm equipment prices rising; however, the present farm finance uncertainty leads farm operators to be more judicious about equipment replacement and upgrades. With prices of new implements reaching $500,000, this raises important financial questions for the farm operator. Is investing in a new planter money well spent? Does this new wave of expensive technology provide a significant financial gain over the earlier model planter being traded in? Specifically, aside from the time and cost savings of a newer model planter—made possible by improved efficiency (e.g., larger planters cover more acres, new planters offer more precision) and less downtime (i.e., less time needing repairs means more time in the field)—does a new planter positively impact yield sufficiently to justify the upgrade cost? Although planter equipment manufacturers promote that newer is better based on public research trials, no research specifically addresses this question outside of controlled experiments. Companies do follow generally accepted research protocols, but analyzing a larger set of yield data from commercial farms can help to validate, or refute, claims.

We hypothesize that a newer planter model yields a higher yield relative to an older planter model on a per-acre basis. This hypothesis is tested using a subset of National Corn Growers Association yield contest data from 2016 to 2023. The data stem from producers implementing high-yielding management practices, and they represent nearly 5,000 entries, which disclose management practices, genetic selection, and equipment use. We present three models that vary by how corn yield is specified: an absolute entry yield, an entry yield relative to the county average, and a percent difference between the entry yield and the county-average yield. The latter two specifications control external events (e.g., weather, location, planting date). We use a subset of the data to isolate planter models with easy-to-find introduction dates and other data needed for this analysis.

Production agriculture has always been a business of uncertainty beyond the farmer's management control. This has driven large investments into innovating agricultural risk mitigation products and tools, including crop insurance, futures markets, drought-resistant hybrids, and countless other production technologies. One important risk factor that has received significant interest involves crop planting practices (De Bruin and Pederson, 2008; Lauer and Rankin, 2004; Liu et al. 2004a; Liu et al., 2004b; Nafziger, 1994). In addition to the upfront expenses of the seed, fuel, and labor, several other risk factors come into play. Seedbed conditions, hybrid selection to match soil and management, planting windows, upcoming weather, planting width, planting depth, seed spacing, and plant population are all important at this stage. For this reason, planter choice is perceived to be important, as newer models offer innovations to better control a number of production factors. During the past 30 years, new brands and models of planters have been introduced. Table 1 illustrates examples of planter models by range of introduction years.

Progressive Farmer ran an eight-part series on "The Art of Planting" during Spring 2015. Jim Patrico, *Progressive Farmer* senior editor, shared anecdotes of why producers buy newer planters or should update. Increased planter width and faster planting speed lead to more acres being planted faster, for example, which is critical to wrap up planting during opportune times of good weather, particularly as farms get bigger. Patrico also pointed to the importance of good stands (i.e., optimal seed depth, optimal seed placement) enabled by newer planters.

Technology adoption has long been of interest to agricultural economists and farm managers. Grilliches (1957) famously studied the adoption of hybrid corn seed, arguing that technological diffusion was due to differences in economic incentives and the profitability of innovation. For the current research, Grilliches' premise of technology adoption follows the line of thinking that a newer planter produces more profit per acre, so larger farmers are more likely to justify a newer planter's cost. That is, the indivisibility of the technology is likely to discourage adoption—or at least delay adoption—by decision-makers with farm sizes below a critical limit because adopting new equipment may only be profitable for farms larger than the critical limit (Just, Zilberman, and Rauser, 1980).

The current analysis is conducted using linear multiple regression techniques to separate the impact of choice of planter model age from management decisions, nutrient application levels, and location and weather effects. Therefore, it accounts for production practices reported in contest entries, which may differ from the practices used by the average producer. The findings suggest some interesting relationships between planter age and corn yield that carry over from high-yielding management to whole-farm management. The results inform practitioners of the yield impact of upgrading to a newer generation planter instead of trading in the planter or investing in a precision upgrade kit. Furthermore, the findings offer insight into how equipment technology has positively impacted the long-term upward national corn yield trend.

MODEL

Multiple linear regression is used to separate the bushel-per-acre yield impact from other factors thought to impact yields. The model is specified three times for three dependent variables: entry yield, entry yield less the USDA National Agricultural Statistics Service (NASS) county-average yield, and percentage difference between entry yield and NASS county-average yield (% difference = [entry yield – NASS county-average yield]/ NASS county-average yield). The explanatory variables are the same for each estimated model. To explain the variation in yield contest entry *i* in year *t*, the following model is specified:

$$\text{Yield}_{it} = \alpha_0 + \alpha_1 \bullet \text{Irrigation fixed effect}_{it} + \alpha_2 \bullet \text{Conservation-till fixed effect}_{it} + \alpha_3 \bullet \text{Nitrogen applied}_{it} + \alpha_4 \bullet \text{Nitrogen applied squared}_{it} + \alpha_5 \bullet \text{Phosphorus applied}_{it} + \alpha_6 \bullet \text{Phosphorus applied squared}_{it} + \alpha_7 \bullet \text{Potassium applied}_{it} + \alpha_8 \bullet \text{Potassium applied squared}_{it} + \alpha_9 \bullet \text{Micronutrients applied}_{it} + \alpha_{10} \bullet \text{Seed planting population}_{it} + \alpha_{11} \bullet \text{Seed planting population squared}_{it} + \alpha_{12} \bullet \text{Seed treatment fixed effect}_{it} + \alpha_{13} \bullet \text{Plant insecticide treatment fixed effect}_{it} + \alpha_{14} \bullet \text{Plant fungicide treatment fixed effect}_{it} + \alpha_{15} \bullet \text{Cow manure applied fixed effect}_{it} + \alpha_{16} \bullet \text{Swine manure applied fixed effect}_{it} + \alpha_{17} \bullet \text{Poultry litter applied fixed effect}_{it} + \alpha_{18} \bullet \underline{\text{Early planter model fixed effect}}_{it} + \alpha_{19} \bullet \underline{\text{Middle-period planter model fixed effect}}_{it} + \alpha_{20} \bullet \underline{\text{New planter model fixed effect}}_{it} + \sum_g \alpha_{20+g} \bullet \text{Series of seed genetics fixed effect variables}_{it} + \sum_h \alpha_{20+g+h} \bullet \text{Series of harvester fixed effect variables}_{it} + \sum_s \alpha_{20+g+h+s} \bullet \text{Series of state fixed effect variables}_{it} + \sum_y \alpha_{20+g+h+s+y} \bullet \text{Series of year fixed effect variables}_{it} + \varepsilon_{it}$$

The empirical model specified above incorporates most of the data fields reported by producers who enter the National Corn Growers Association yield contest. The exceptions are the data are absent for planting date and crops planted in the prior year. Planting date is included in the second and third models when considering the county-average yield. Planting date has been found to be a significant factor contributing to corn yield in high-yield and normal production practices (Long, Assefa, Schwalbert, and Ciapitti, 2017). We do not have data on crops planted in the prior year. The right-hand-side variables are factors expected to affect entry-to-entry (or producer-to-producer) yield variability.

Irrigated land is expected to have a higher yield than nonirrigated land. A binary variable is used to account for entries that indicate irrigation. In the later specifications of yield, relative yield difference (model 2), or percent yield difference (model 3), the binary variable accounting for irrigated entries versus nonirrigated entries captures both entries relative to an irrigated average (i.e., where NASS reports an irrigated yield) and whole-county average (i.e., where NASS reports only a whole-county average, and the entry is tagged as irrigated).

The National Corn Growers Association yield contest has up to 11 competition categories, including no-till, strip-till, and minimum till. For the current study, these three categories were lumped together into the binary variable conservation till. A binary fixed effect variable accounts for entries reporting the use of conservation till. We expect entrants using conservation till to have yields less than conventional till entrants. Validation of our hypothesis is that the contest has separate classes for conventional and conservation tillage practices.

Three variables account for nutrient applications (i.e., nitrogen, phosphorus, potassium). Higher levels of nutrient applied should increase yield. The nutrient level variables are specified in quadratic form to account for a nonlinear relationship between yield and nutrient applied. Given this is a yield competition, producers taking part likely apply nutrients at levels thought to enhance yield, even when not economically viable. The expectation for nitrogen is a positive linear relationship, but there is no positive, or negative, expectation whether more and more pounds of nitrogen lead to yield increasing at an increasing, or decreasing, rate. Both phosphate and potassium build up over years, and a one-year impact may not be noticeable in a model like the one estimated here.

For the case of high-yield management, we allow the model to speak to how the pounds of phosphate or potassium applied for a specific crop year contribute to corn yield in the same year. A separate binary (0 or 1) variable was specified to account for whether the entrant reported applying micronutrients. Contest data show the level of micronutrients applied; however, we did not need to specify such a granular model for testing our hypothesis of how planter age affects corn yield. For the present analysis, we used the binary variable to account for micronutrient applications on entries indicating the application of micronutrients, which contribute to increasing corn yield through kernel weight and plant health. We expect entries with applied micronutrients to report higher yields.

Because an optimal seeding rate (e.g., seed spacing, ear count) should maximize yield, seeding rate population and seeding rate population squared (i.e., quadratic terms) are included to identify the seeding rate impact on yield over the range of seeding rates reported by entrants.

The next three variables account for plant treatment applications used before and during season (i.e., seed treated, insecticide applied, fungicide applied). Given that the summary statistics indicate few entrants apply insecticides or a fungicide treatment and fewer than three-quarters plant treated seed, we expect the data will show why these adoption rates are low. Either fungicide or insecticide application could be a management response to sustain good plant health after an observation during the growing season. Therefore, we have no *a priori* expectation on how these factors may impact yield per acre. We let the data inform us of the yield impact.

The entrant-applied effluent was noted as three separate dummy variables for cow manure, hog manure, or poultry litter. Like the case of micronutrients, we know the level of manure or litter applied; however, we did not need to specify such a granular model for testing our hypothesis of how planter age affects corn yield. For the present analysis, we used the binary variable to account for manure or litter application. In addition to nutrients, cow manure or poultry litter contribute organic matter, which helps plants take in nutrients such as nitrogen, phosphorus, and potassium. We expect effluent use to have a positive effect on corn yield.

The planter model was set into four age categories: old, early, middle, and new. If a planter model was first introduced in one of these age categories (see Table 1), then the entrant was assigned a 1; otherwise, the entrant had a 0 assigned. The old-generation category is set as the default. We expect newer planters to contribute to a higher yield relative to the oldest generation models in the data with increasing magnitude from early- to middle- to new-generation planters. The size of the yield impact is to be determined from the empirical model.

The study accounts for seed company brand by using a set of fixed effect variables. We are working with a subset of the overall high-yield management data and purposefully avoid reporting individual seed brand impacts on yield specifications. We don't want to "pick" winners. Also, licensing agreements between genetics companies point to varieties being derived from similar parent genetics. The focus is on whether seed genetics brand variables collectively have a significant effect on yield variation. We use an F-test statistic to test whether all brands together help in explaining yield variation.

The harvester brand was accounted for through a series of 0 or 1 fixed effects variables for entry *i*. Like the description of seed genetics fixed effects and keeping the focus away from picking "a winner," the intent is to measure whether knowing harvester brand significantly explained yield variation. We use an F-test statistic to test whether all harvester brands together help in explaining yield variation.

A series of 0 or 1 fixed effect variables indicate the state of entry *i*. This is a yield contest, only the best land is used for entries, and entries occur from across states. Therefore, we have no *a priori* expectation on how region will affect yield per acre. To conserve space, we evaluate spatial effects in totality by reporting an F-test statistic to test whether state, in general, helped in explaining yield variation.

The dataset had nine years of data, so a yearly fixed effect—equal to 1 for the specific year and 0 otherwise—is included. The default is 2016, and a fixed effect variable is set to 1 when the yield recorded is for fields using irrigation; otherwise, a 0 is used. Because growing conditions vary by year and location and the fixed effects account for a particular year's average across all observations, there is not *a prior* expectation of how yield, on average, differs by year.

DATA

This study's underlying dataset comes from entries into the annual National Corn Yield Contest, which the National Corn Growers Association administers. Using data from 2016 to 2023, this study represents high-yielding 10-acre corn plots from entrants across the country. Data on the use of different inputs, management practices, and machinery and the resulting yields for 4,818 observations were analyzed. Of the nearly 19,000 observations available from the full yield contest dataset, several observations were dropped due to incomplete data needed for the analysis. We eliminated fewer than 100 observations due to outlier values (e.g., 1,200 pounds of potassium applied per acre). Because two of our models analyzed contest entry yields relative to NASS-surveyed county-average yields, contest entries located in a county without a reference county-average NASS yield were dropped. Finally, with a focus on planter model age, we dropped observations where we did not classify the model age of the planter. We chose the most common planter models in the data to analyze and dropped some observations to ensure input errors do not interfere with analysis.

Summary statistics are given in Table 2. For binary variables, the mean value indicates the percentage of cases with a trait or practice. For example, the mean of 0.34 for irrigated entries indicates that 34% of the observations represent irrigated entries. Statistics for all other variables represent numerical values in their respective measurements, so the mean of 93.64 for potassium indicates about 94 pounds of that nutrient were applied on average on a per-acre equivalent.

The data include continuous variables for yield, seed population, and fertilizer levels, and the rest of the data consist of binary variables representing a wide variety of factors such as the seed brand; the type(s) of herbicide used; the type of harvester used; whether the grower chose to employ insecticide, fungicide, insecticide, or seed treatments; whether synthetic fertilizer was replaced or supplemented with cow manure, hog manure, or poultry litter; and the state in which each field was located. We use the statistical term fixed effect variable in reference to binary variables assuming a value of 1 if “yes” and 0 if “no.” Controlling for these other factors allows us to isolate these effects while obtaining useful information about the effects of planter age categories on yield.

Three measures of yield are evaluated. The first is the yield entry, the second is the difference between the yield entry and the NASS county-average yield for the specific observation year, and the third measure is the percentage difference between the yield entry and the NASS county-average yield for the specific observation year. Because entries include irrigated and nonirrigated yields, we assigned each yield entry to one of three categories of NASS county-average yield: irrigated yield when NASS reported an irrigated county-average yield (i.e., irrigated county yield), a nonirrigated yield for a county where NASS reported an irrigated and nonirrigated county-average yield (i.e., dryland county yield), and a county with only a NASS nonirrigated yield reported (i.e., standard county yield). Most entries fall into the standard county yield category, and the fewest entries are for dryland county yield.

Contest entry yields averaged 268.32 bushels per acre with a minimum of 119 bushels and a maximum of 406.95 bushels. The standard deviation of 38.59 implies that observations in the sample were, on average, greater or less than the mean by about 40 bushels. Figure 1 displays the frequency of corn yields in bushels per acre. Most participants achieved between 150 bushels per acre and 340 bushels per acre. Hence, though the 4,818-observation sample spanned a nearly 400-bushel difference, most of the data concentrated within the 200-bushel difference, and much of the remaining data were near those numbers. Figure 2 shows the percent difference of the contest yield entry to the NASS county-average yield. Most entries lie between 0% and 100% above the county-average yield. Notice the long right-side tail for extreme high-yielding entries.

More than half the land was conservation-tilled (i.e., no-tilled, strip-tilled, minimum tilled). Nitrogen, phosphate, and potassium exhibited respective means of 250, 87, and 94. The average seed population was roughly 34,000 seeds per acre. Insecticide and fungicide usage was present in about 10% and 17% of observations, respectively, and seed treatment was present for 73% of observations. Cattle manure, hog manure, or poultry litter were applied for 6%, 3%, and 8% of observations, respectively. We do not list seed genetics brands or harvester brands separately. Our intent is to account for these factors but not evaluate and rank seed genetics providers or harvester companies. We evaluate the overall contribution of genetics and harvester to yield variation, which will be discussed more in the Results section. To conserve space, we do not break down observations by state, but in general, the breakdown of entry state location follows state-level production relative to the country overall. The one exception, Michigan, represents 14% of observations in the contest entry dataset.

RESULTS

Models were estimated in the economic and statistical software Shazam. Using the explanatory variables detailed in the model section, the three models explained between 32% and 46% of the variation in corn yield entries. Model specification was checked for these continuous variables: seed population, nitrogen, phosphate, and potassium. The data did not indicate a preference for a particular nonlinear specification of these variables. The quadratic specification was used because of straightforward interpretation of the coefficients.

Table 3 displays the regression results that show the estimated impact of these factors on corn yield in bushels per acre for models 1 (i.e., third column) and 2 (i.e., fourth column). Model 3 (i.e., fifth column) is the percentage yield impact from county-average yield. Average NASS county-average yields across the period of study were 136.9 for dryland, 180.7 for standard, and 202.9 for irrigated. Several estimated coefficients had a statistically significant impact on corn yield at the 1% level. For instance, entries with a fungicide application, on average, had increased corn yield by 2.09 bushels in absolute yield (column 3), 2.20 bushels in relative yield (column 4), and 2% in percentage difference yield (column 5). Irrigated entries, also, tended to hold a yield bump over nonirrigated entries. This outcome is not surprising.

Entries reporting the use of conservation tillage practices, relative to conventional tillage practices, had no yield difference across any of the three models. This result indicates producers may save on tillage costs by using conservation tillage but not risk a drop in yield. Insecticide application had no impact on any of the yield models. Seed treatment impact was only significant for the entry yield model (column 3).

The significant effects of seed population and seed population squared are evidence of the nonlinear effect of increased seeding rates on corn yields. For the data analyzed, the seeding rate impact on yield increases for each 1,000 seeds planted, but the quadratic term indicates the seeding rate increases yield at a decreasing rate per 1,000 seeds. Notably, this result isn't itself enlightening because no seeds in the ground means no yield. Appropriately accounting for planting rate variation will separate out the impact of seeding rate on yield to isolate the impact of planter age on yield. The same holds for all variables in the model.

Of the three nutrients included in the analysis, only nitrogen was found to have a statistically significant impact on yield and only for the yield (column 3) and relative yield (column 4) models. For the percentage difference yield model (column 5), additional pounds of nitrogen applied had no impact on high-yield management corn yield. When statistically significant, the impact of applying more nitrogen on yield was positive. Neither additional pounds of phosphate nor potassium were found to impact corn yield at a significant level. Applying a trace element only statistically, and significantly, positively impacted the entry yield model (column 3).

Applying cow manure, swine manure, or poultry litter had varied impact on corn yield by model. In the subset of contest entries analyzed, cow manure applied to a plot had a positive and significant impact on yield by a much larger magnitude than hog manure or poultry litter.

Other than for harvester, in general, the inclusion of the series of variables statistically and significantly impact yield. Thus, the inclusion of each series of binary variables contributes to explaining entry-to-entry variation in corn yield and validates the inclusion of these variables. The finding that the harvester has no impact on entry yield is not surprising. Most farm operators select harvester brands and models based on reliability and service convenience.

As for the impact of planter model age on yield, the results are consistent across all three models explaining corn yield variation in entry yield, relative yield, and percentage yield. The reported values are relative to the oldest generation planters (see Table 1). As expected, the newest generation of planter provides a yield benefit compared with prior-generation planters. Focusing on the relative yield model (column 4), the results found the newest generation planter adds more than six bushels per acre in high-yield managed plots relative to the county average. Given the dependent variable is a relative measure, this impact is rather large for a single management decision factor. The robustness of this finding about new-generation planters indicates a similar impact on all other ground a farmer plants to corn.

Interestingly, the marginal contribution to yield impact gets larger as the generations of planters age relative to the oldest planters observed. This indicates that planter technology innovations' impact on yield increased over time and contributed to the positive corn yield trend observed nationally over time. It will be interesting to see if future generations of planters can continue to provide such large leaps in innovation that lead to an increased corn yield impact.

Assuming $4-per-bushel corn, each 1,000 acres planted to corn by a newest generation planter adds up to $24,000 in revenue relative to an earlier generation planter. Larger operations will observe a faster return on investment than smaller farms.

Given a new-generation planter's cost can exceed $500,000 and new planters incur operating expenses, farm operators are likely to scrutinize the choice to replace an existing planter, particularly if farm financial conditions weaken in response to low commodity prices. If using precision upgrade kits enables a farm to realize a large portion of the yield increase offered by new-generation planters—and the kits provide cost-saving conveniences and reliability—then the farm operator can invest in precision upgrades at a portion of the cost of a new planter.

CONCLUSIONS AND CONSIDERATIONS

Using a subset of National Corn Yield Contest entries submitted between 2016 and 2023, this study found the newest generation planter models relative to older models—after accounting for other management factors—positively impact high-yield management corn yield by up to 12 bushels per acre relative to the oldest model planters used by contest entrants and marginally six bushels per acre between the latest generation planters and second newest generation planters. (The oldest planters entered production in the late 1970s and early 1980s.) We analyzed three measures of corn yield: absolute entry yield, relative entry yield to the NASS county-average yield, and percentage difference of entry yield to the NASS county-average yield. The latter two models account for external factors such as planting conditions and weather during the growing season.

Assuming the six-bushel-per-acre yield bump from upgrading to a newer generation planter and $4-per-bushel corn, each 1,000 acres of corn planted adds $24,000 in revenue to the farm business using a newer generation planter relative to an earlier generation planter. Larger operations will observe a faster return on investment than smaller ones. Our findings are consistent with industry reports of strong new planter sales during the past few years—with annual sales growth rates of at least 2% for more than 30% of farm equipment dealers (Thorpe, 2024).

This study's results are threefold related to the literature on innovation and adoption. First, we have shown economic evidence of planter adoption diffusion following Grilliches' famous supposition (i.e., bigger farms adopt technology sooner). Second, we confirm why planter sales increased during times of high commodity prices (i.e., not as much land is needed to reach the point of economic justification to upgrade a planter). Third, when the price spread between new-model planters and recent-model planters is wide, producers may look to precision upgrades as a more cost-effective alternative to capture gains of new technology but use an older generation planter body. This is consistent with the industry trend of more companies offering precision upgrade planter kits (e.g., John Deere precision upgrades, Kinze upgrade kits, Precision Planting). As commodity prices and farm income decline, farm managers are likely to face capital constraints and closely assess whether to upgrade to newest generation planters.

Another finding of this research is associating planter technology with the long-term corn yield increase in the U.S. Other factors such as genetic improvement and managerial skill enhancement also likely encouraged the uptick in national corn yields. Between 1980 and 2023, the U.S. average corn yield per acre increased by approximately 100 bushels. Although new planter adoption and the contribution to average yield across large geographic areas show a lag (i.e., not all farmers adopt new technologies at once), the contribution of the planter to trend line yield gains could be about 8% to 10% of the yield improvement recorded during the 40-year period.

We would be remiss to not summarize the study's weaknesses. First, we acknowledge that older model planters, as well as newer model planters, may have add-on kits that require significant investment. Second, the strategy driving implementation of high-yield management practices differs from the strategy that favors conventional farming practices. Plus, the skill at implementing high-yield practices influences crop yield potential. Finally, we recognize newer model planters offer the agronomic and economic advantages of split-row capabilities across crops, different row spacing opportunities, additional rows for faster planting, larger seed capacities, and faster in-field towing. These factors were not reflected within the data used here.

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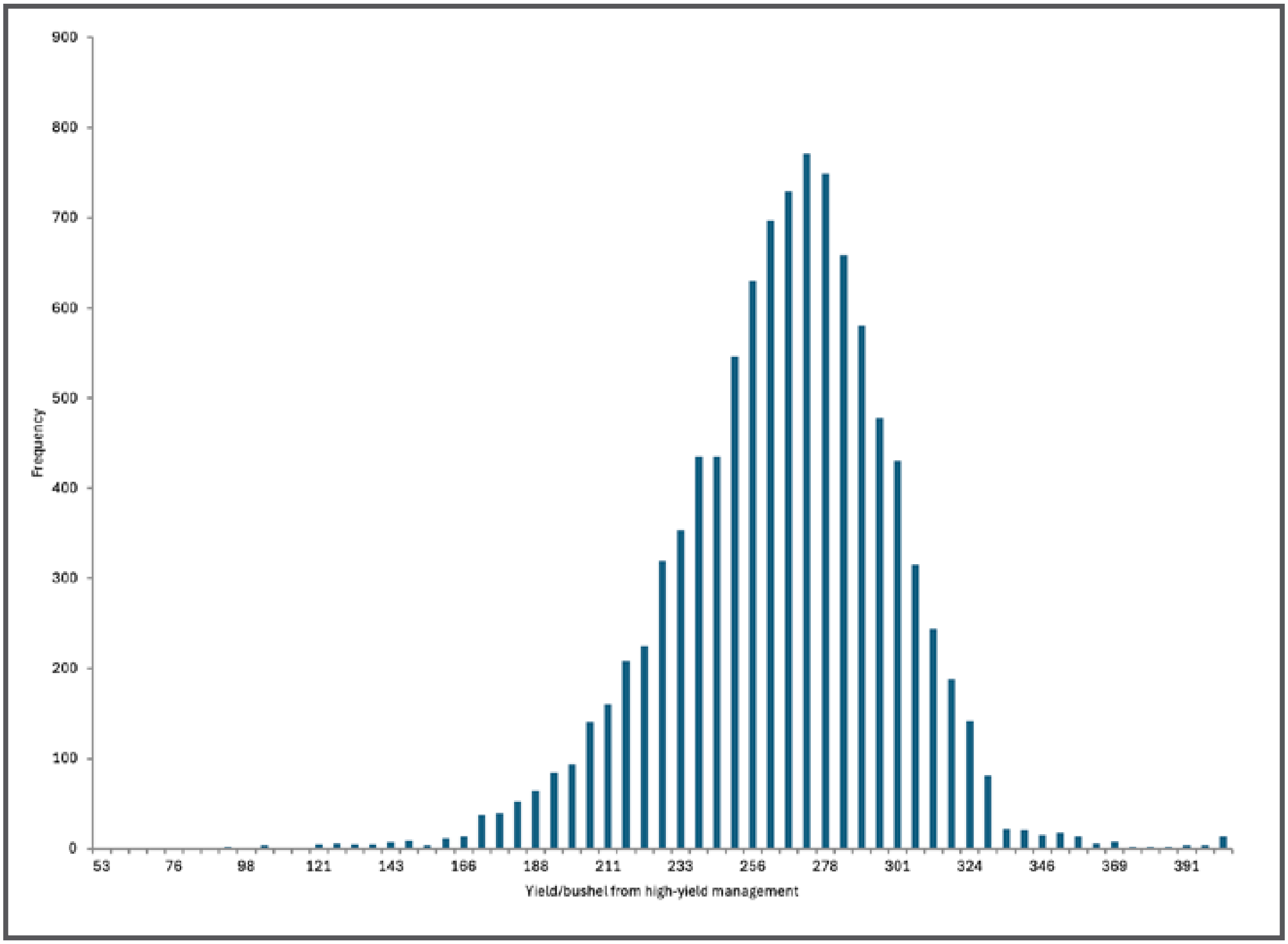


Figure 1. Distribution of corn yields from National Corn Yield Contest entries*

* The data originates from a subset of total entries submitted from 2016 to 2023.

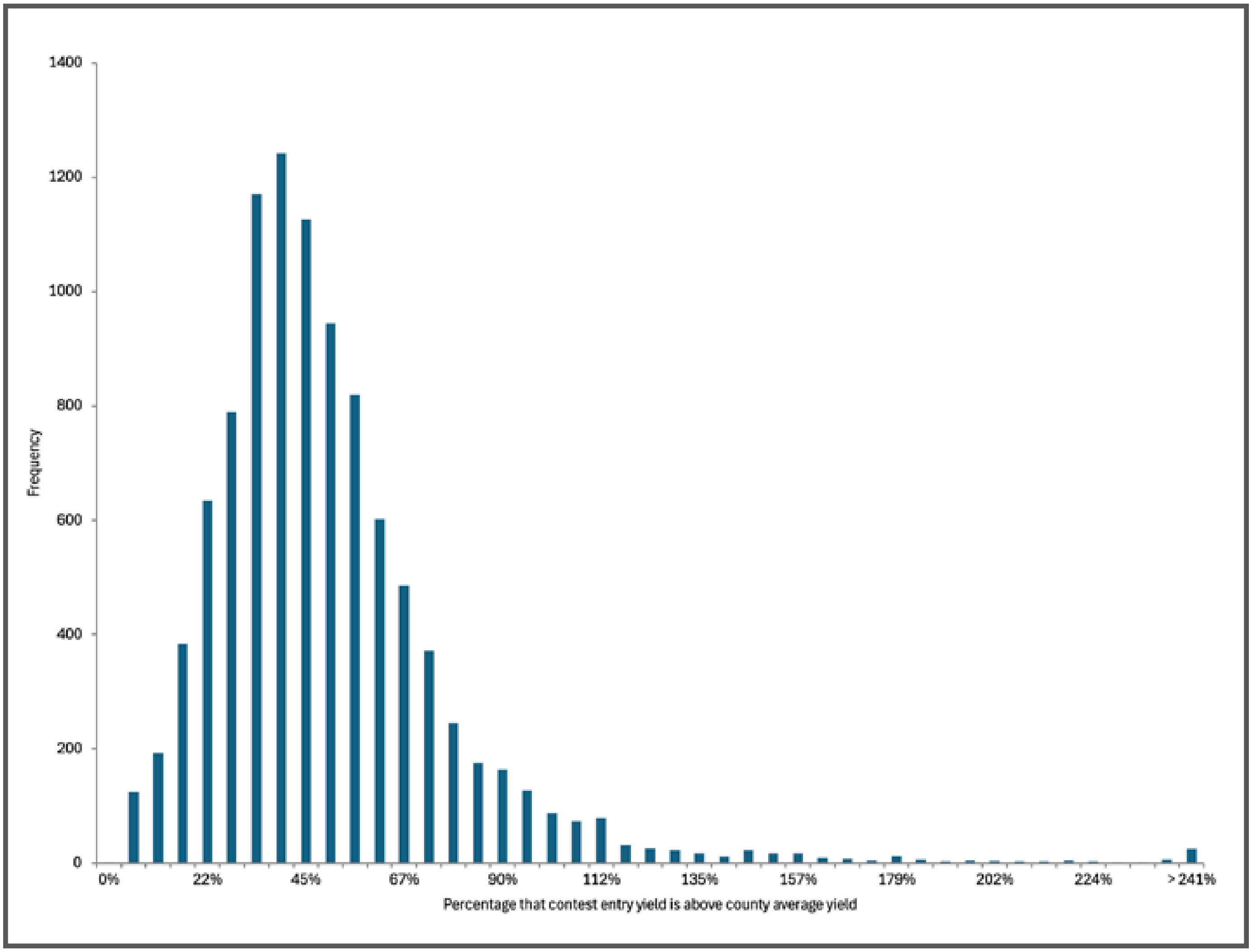


Figure 2. Distribution of corn yields from National Corn Yield Contest entries relative to county-average corn yield*

* The data originates from a subset of total entries submitted from 2016 to 2023.

Table 1. Planter Models Grouped By Model Introduction Year

Brand	Model	@ Year Introduced
Oldest Generation		
John Deere	7200/7300	1986
John Deere	7000	1987
Case/IH	900	1989
White	5100	1979
Old Generation		
Case IH	1200	2003
John Deere	1720,1780, 1760	1995-1997
White	6100, 6200, 8500, 8700	1991-1992
Kinze	3200, 3600, 3650, 3800, 3500, 2600	1995-2004
Middle Generation		
Kinze	4900, 3660, 3140	2009-2014
John Deere	1775, 1795*, DB*	2010-2013
Case IH	1265, 1250, 1240, 1255, 1235	2007 – 2014
White	8824, 9180, 9800, 9200	2009 – 2012
Monosem	Custom built	varies
Newest Generation		
Kinze	4905	2021
White	9222	2017
Case IH /	2150, 2130, 2160, 2140	2013-2018
CNH	4900	2013

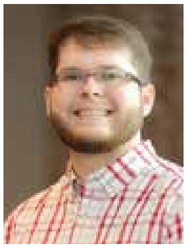
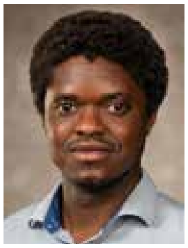
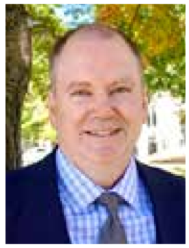
Notes: Approximate introduction years determined by monitoring planter sales and age specification on Fastline.com. The earliest year of models listed for sale were chosen for grouping. John Deere's model DB and 1795 planter models have existed since the middle generation, and the newest generation of these models offer upgrades to earlier models. We were unable to separate out which generation to allocate these planters.

Table 2. Summary Statistics of 4,818 Observations from Subset of National Corn Yield Contest Entries, 2016 to 2023					
Coefficient	**Unit**	**Mean**	**St.Dev.**	**Minimum**	**Maximum**
Yield	Bushels/Acre	268.32	38.59	119	406.39
Difference from county average	Bushels/Acre	84.42	35.13	0.46	329.61
% above county average	%	47.7%	30.6%	0%	560%
	Year				
2016	*Default*	0.01		0.00	1.00
2017	Yes=1 No=0	0.01		0.00	1.00
2018	Yes=1 No=0	0.09		0.00	1.00
2019	Yes=1 No=0	0.19		0.00	1.00
2020	Yes=1 No=0	0.21		0.00	1.00
2021	Yes=1 No=0	0.18		0.00	1.00
2022	Yes=1 No=0	0.17		0.00	1.00
2023	Yes=1 No=0	0.15		0.00	1.00
Management Practice					
Irrigated	Yes=1 No=0	0.34	0.47	0.00	1.00
Conservation-till	Yes=1 No=0	0.57	0.49	0.00	1.00
Planting population	1000 Seeds	34.05	3.28	15.00	54.00
Insecticide	Yes=1 No=0	0.10	0.30	0.00	1.00
Fungicide	Yes=1 No=0	0.17	0.37	0.00	1.00
Seed treatment	Yes=1 No=0	0.73	0.44	0.00	1.00
Fertilizer Applied					
Nitrogen	Pounds/Acre	227.04	58.11	80.00	600.00
Phosphate	Pounds/Acre	66.55	56.10	0.00	300.00
Potassium	Pounds/Acre	93.64	75.87	0.00	300.00
Manure/Litter Applied					
Cattle	Yes=1 No=0	0.06	0.25	0.00	1.00
Hog	Yes=1 No=0	0.03	0.18	0.00	1.00
Poultry	Yes=1 No=0	0.08	0.27	0.00	1.00
Planter Model Age					
Oldest	Yes=1 No=0	0.04	0.20	0.00	1.00
Older	Yes=1 No=0	0.42	0.49	0.00	1.00
Middle	Yes=1 No=0	0.42	0.53	0.00	1.00
Newer	Yes=1 No=0	0.12	0.33	0.00	1.00

Table 3. Regression Results of Factors Affecting Corn High-Yield Management (bushels/acre) from 4,818 observations between 2016 and 2023				
Variable	**Unit**	**Dependent variable = absolute yield**	**Dependent variable = yield relative to county avg.**	**Dependent variable = % yield above county avg.**
Average of dependent variable:		262.66	81.42	48%
Management Practices and Input Decisions Impacts				
Irrigated	Yes=1 No=0	5.44**	10.47***	8%***
Conservation-till	Yes=1 No=0	1.10	0.74	0%
Population	1000 Seeds	12.890***	5.33***	4%***
Population – squared	1000 Seeds	-0.13***	-0.44***	-0.4%***
Nitrogen	Pounds/Acre	0.09***	0.09***	0%
Nitrogen – squared	Pounds/Acre	< 0.01	0.001*	0.01%**
Phosphate	Pounds/Acre	-0.01	-0.03	0%
Phosphate – squared	Pounds/Acre	<0.01	<0.01	<0.1%**
Potassium	Pounds/Acre	-0.03	-0.02	0%
Potassium – squared	Pounds/Acre	<0.01	<-0.01	0%
Trace elements	Yes=1 No=0	1.5**	1.07	0%
Seed treatment	Yes=1 No=0	2.04**	0.86	0.3%
Insecticide	Yes=1 No=0	1.17	-1.37	-0.1%
Fungicide	Yes=1 No=0	2.09***	2.20*	2%**
Cow manure	Yes=1 No=0	12.73***	12.68***	6%***
Swine manure	Yes=1 No=0	6.77***	3.34	0%
Poultry litter	Yes=1 No=0	4.13***	8.79***	5%***
Planter Model Impact (relative to oldest generation planter)				
Old generation	Yes=1 No=0	2.61*	1.74	1%
Middle generation	Yes=1 No=0	7.15***	5.00***	2%
New generation	Yes=1 No=0	11.53***	11.69***	7%***
Group Impacts, Management and External				
Seed genetics – management Test of group (F-statistic)		6.74***	4.27***	2.25**
State of entry – external Test of group (F-statistic)		29.18***	30.96***	38.67***
Harvesters – management Test of group (F-statistic)		2.62**	1.34	1.39
Years of entry – external Test of group (F-statistic)		44.84***	11.31***	9.88***
Intercept		-67.66***	-112.98***	-9%***
R-squared		0.46	0.37	0.32

^ *, **, or *** asterisks represent statistical significance at the 0.10, 0.05, and 0.01 levels, respectively

Is PRF Profitable in a Wetter State? Evidence from Arkansas

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Abstract

Despite increased enrollment in Pasture Rangeland and Forage (PRF) insurance since 2016, Arkansas has seen continued low enrollment and low loss ratios. Studies that have assisted enrollment in other forage-producing areas have not been conducted in the Southeast. We address this need by performing a profitability analysis of three distinct counties in the state across different interval selection strategies and wetness years. We find that PRF is profitable in drier to median wetness counties while showing poorer performance in the wettest county. Our results suggest the need for county-specific recommendations for enrollment and interval selection in Arkansas.

INTRODUCTION

Pasture, Rangeland, and Forages (PRF) insurance, a rainfall index (RI) insurance plan offered through the Federal Crop Insurance Program (FCIP), was first introduced in 2007 in a handful of counties and grids. Rather than using county boarders, PRF ratings are based on 0.25- by 0.25-degree longitude and latitude grids across the U.S., except for those bordering Canada and Mexico. The program was designed to solve several issues that were identified when using traditional row crop insurance plans for covering forage crop losses[1]. With PRF coverage expanded to the whole nation since 2016, though, FCIP acreage enrollment increased most as a function of PRF enrollment, moving from 6% of total acres in 2016 to 40% of total FCIP enrolled acres by 2021 (Turner et al., 2023). Further, the primary increase in PRF acreage has been in states where PRF was based on a vegetation index (Belasco and Hungerford, 2018)[2], with uneven adoption trends across the U.S.

Total enrollment in PRF has been highest in the Pacific, Mountain, and Southern Plains regions; the Delta, Lake States, and Northeast regions have seen the lowest enrollment. Total insurable acres are a significant driver of total enrollment across these regions, but other factors also play a role. Key challenges to enrollment that have previously been identified include basis risk, difficulty in selecting coverage intervals, and lack of information about the benefits of enrollment outside of key forage production areas (Zapata and García, 2022). Basis risk refers to the discrepancy between the insurance payout and the actual losses experienced by the farmer, leading to producer frustration when payouts are lower than actual losses. The complexity of interval selection for loss coverage adds to basis risk. In key production areas, research and outreach have helped to reduce such barriers and thereby have aided rapid adoption (Davidson and Goodrich, 2023). However, such research is lacking in regions such as the Lake States and the Delta.

This study aims to address this research gap, namely, by evaluating the profitability of PRF in Arkansas, a key forage production area in the Delta region. The Delta region, and Arkansas specifically, was chosen for three primary reasons. First, PRF enrollment in the region lags behind other forage-producing areas, despite being available since 2016. Second, studies that analyze the performance of PRF are lacking in the region. Third, loss ratios for participating producers in the region have been below 1 since 2018. This reflects a host of issues on the producer and program side that are currently unexplored and serve as a deterrent to participation. In addition, with Arkansas among the top 10 wettest states in the country and anecdotal evidence of poor PRF viability in wetter regions, focusing on precipitation differences across grids in the region may offer some insights. The overall intent was thus to uncover information that producers and policymakers alike can utilize to help strengthen protections for ranchers and forage producers in the region.

Since basis risk, interval selection, and low loss ratios are key factors, our analysis focuses on comparing financial performance with no PRF insurance to three different interval selection strategies described further below. These strategy comparisons were repeated for grids in the wettest, driest, and median wetness counties to assess implications of precipitation on the performance of PRF.

Our results indicate that, across all interval selection strategies, PRF performed better than the no insurance option in the dry and median wetness counties. However, more careful interval selection strategies in wetter counties is necessary, as cases existed where the no PRF protection option was most profitable. Such events are possible when excess precipitation does not trigger an indemnity payment despite forage losses from too much rain. Hence, our work suggests the need for a state/location-specific understanding of PRF for proper farm management and forage protection.

BACKGROUND

Arkansas is one of three states in the Delta region of the mid-southern U.S., bordered in the East by the Mississippi River and the Great Plains in the West. Forage production is an important source of livestock feed, with 1.5 million acres in hay and 4.5 million acres in pasture. Regions with high PRF adoption typically experience intermittent rainfall. Examples are parts of Texas, California, and much of the Great Plains that rely heavily on forage grown during the wet season to last during the months with less precipitation or periods of drought. Because of this reliance on wet-season growth and the prevalence of drought, PRF is a logical choice to help mitigate weather-related risks.

By comparison, Arkansas experiences a more consistent and higher level of rainfall throughout the year, which reduces the perceived need for PRF insurance among local farmers, leading to lower enrollment rates. Additionally, Arkansas is characterized by smaller cattle ranches and lower forage production compared to the larger, more developed operations found in the high-adoption regions. According to Barnett and Mahul (2007), weather index insurance, including products like PRF, provide a necessary safety net by offering financial protection based on objective weather indices, rather than actual loss assessments. This particularly benefits smaller operations that otherwise struggle to recover from the economic impacts of severe weather. By providing timely indemnities when weather conditions suggest a high likelihood of forage loss, PRF insurance helps smaller operations maintain their livestock, avoids distress sales, and ensures long-term viability despite adverse conditions. However, smaller operations may find the cost of premiums unappealing without a clear understanding of the potential benefits. Hence, the need for information to reduce the complexity of using PRF exists. Furthermore, as shown in Figure 1, Arkansas has the second lowest loss ratio of all states that have some level of PRF participation, with a loss ratio well below 1, implying that PRF users on average spend a dollar on premiums to receive 36 cents in indemnity payments. Policies offered through the Federal Crop Insurance Program are mandated to produce loss ratios equal to 1. Hence, low loss ratios imply potential rating issues or a lack of optimal utilization of the policy. We focus on the latter.

PRF, Forage Production, and Herd Management

Forage loss, particularly due to drought, poses a significant threat to livestock production, which is a major component of the agricultural economy. When forage resources become scarce, the direct consequence is a reduction in available feed for livestock, which can potentially lead to a series of negative outcomes. Without the necessary forage, livestock producers may be forced to reduce herd sizes through premature selling of animals, often at unfavorable market prices, leading to long-term economic losses. Moreover, a reduction in herd size may disrupt breeding programs and reduce the future productivity of the operation, further worsening the financial strain on producers. The failure to maintain sufficient forage supplies can also increase reliance on purchased feed, which is generally more expensive and can further wear away at profit margins. In some cases, persistent forage shortages can lead to the degradation of land, as overgrazing becomes a common response to limited forage availability. As Finch et al. (2016) discuss, drought conditions not only reduce forage availability but can also lead to significant environmental damage, including soil erosion and loss of vegetation cover. This degradation can have long-term environmental impacts, reducing the land's ability to support livestock production and compromising the sustainability of agricultural practices in the region (Daryanto, Wang, and Jacinthe, 2017).

Additionally, the economic strain resulting from forage loss can have community impacts as local businesses rely on a successful agricultural sector. Mitigating forage loss is crucial, not only for maintaining the capability of livestock operations but also for protecting the broader economic and ecological health of agricultural regions. Without sufficient mitigation strategies, the impacts of forage loss can be severe and enduring, affecting both current and future generations of agricultural producers.

Structure of PRF and Limits to Protection

PRF protection is based on an index of rainfall that occurs in a two-month interval in a 0.25-degree by 0.25-degree grid, with RI relative to the average rainfall of the previous 30 years; producers purchase coverage based on the grid(s) in which their fields are located. To use PRF, a producer must choose at least two specific two-month intervals, potentially based on the months the producer believes to be most important for forage production. Intervals must be selected such that at least one interval separates them, as intervals cannot have consecutive starting months. For example, a producer may decide that the late winter/early spring months are the most important for forage growth, a time that peaks in late spring to early summer in their grid. As such, the producer may select the January-February interval and a March-April or later interval, but not the February-March interval as it would overlap with the first (January-February) interval chosen.

Upon selecting intervals, a producer then decides the percent of production to cover in each grid, the sum of which must total 100% with no interval covering more than 60% or less than 10% of the total coverage value in any individual grid. The producer then decides the percent of value they will cover by choosing their coverage level. The coverage level ranges from 70% to 90% and increases in 5% increments[3]. Finally, the producer decides their productivity factor, which varies based on whether the producer is covering grazing acres or hay acres. A higher productivity factor commands a higher payment if a PRF triggering event were to occur, however, the insurance premium is also higher for higher productivity factors. The payment rates upon a trigger are determined by the County Base Value (CBV), which varies by grid and productivity factor and is a regional estimate of the monetary value of forage for an acre assigned by the RMA.

In many areas, and specifically in Arkansas, these decisions are complex. In a state where rainfall is relatively consistent, determining intervals to select that are most important for forage growth can be challenging. Basis risk, that is, when the insurance payouts based on the RI do not reflect the actual losses experienced by the farmer, also complicates matters. While index insurance programs are beneficial in reducing organizational problems and other issues such as adverse selection and moral hazard, imperfect correlation between the index (e.g., rainfall) and actual losses experienced by policyholders are problematic (Miranda and Farrin, 2012). This basis risk is larger in regions with consistent or less variable rainfall, which is where the correlation between the index and actual forage conditions can be weak, compromising the fundamental purpose of index insurance by not delivering the financial protection needed during adverse conditions (Clarke, 2016). With Arkansas's relatively stable rainfall patterns, the perceived need for single-peril RI insurance declines, making it harder for farmers to justify the premium costs. Past work has shown that the perceived value of insurance is closely linked to the frequency and severity of adverse weather events. When these events are infrequent, as is often the case in Arkansas, farmers may view PRF as an unnecessary expense rather than a valuable tool for risk management (Smith and Watts, 2019).

Therefore, we consider the effectiveness of PRF across different interval selection strategies and across counties with different levels of average wetness across different years of varying wetness. Our aim is to determine the degree to which interval selection affects PRF outcomes and whether outcomes change based on average county precipitation. We develop three simple strategies to answer these questions and compare each to the no PRF option. The first strategy involves coverage during historically significant forage months, including May through August. The second strategy focuses on peak forage protection, using the analysis below to identify and cover intervals most strongly associated with peak forage growth. The final strategy seeks to leverage basis risk by minimizing false negative probabilities and maximizing false positive probabilities that are described further below. Leveraging basis risk improves the alignment between the policy and actual forage loss.

METHODS

We inspect three grids with the largest number of pasture acres within three counties that vary with respect to precipitation (high, medium, and low)[4]. The selected counties are Boone County (low precipitation county; 11.5% less than 30-year normal state precipitation), Lee County (median precipitation county), and Polk County (high precipitation county; 16.6% more than 30-year normal state precipitation). The selected counties are shown in Figure 2.

Demand for PRF has closely followed rainfall patterns, with dryer areas seeing higher adoption of the policy versus the opposite case for higher-than-average rainfall regions in Arkansas. Hence, we evaluate whether program benefits vary across the state based on average rainfall. Further, within each county, we evaluate how the three different PRF interval selection strategies would have performed in five separate years, in the driest, wettest, median, and the 25th and 75th percentile years in terms of rainfall over the last 30 years (1994–2023). Average performance across those five scenarios and three counties with the three interval selection strategies are then compared to the no PRF strategy.

We began by devising three interval selection strategies that may be interesting to producers. The first strategy, which we call the Near Peak Forage Months strategy, assumes that rainfall in the months closest to historical peak forage production months are the most important for forage protection. Hence, the strategy selects intervals that are near the beginning of the peak forage months and the most adjacent interval after. The intuition for this strategy is that in years where peak forage is low due to low rainfall, correlations in weather across months might also suggest that rainfall before and after peak forage would be below their 30-year normal. Hence, to implement the strategy, we determine peak forage months in each county by observing the average 30-year peak Normalized Difference Vegetation Index (NDVI) values for each county. Figure 3 highlights peak forage months in the three selected counties. We assign a 50% value to each selected interval under this strategy, choosing the interval immediately prior to the 30-year peak month and the interval immediately following the 30-year peak month to cover four months of forage production centered around the peak forage months (June and July).

The second strategy, called Peak Forage Protection, is more analytical. In this case, we select two intervals within a year that are most impactful on peak forage months based on their RI. Various agroecological factors may mean that specific months are most important for forage growth despite not being within the two-month peak forage growth window. Hence, this strategy seeks to choose two intervals most likely to pay when a forage loss occurs. Like Keller and Saitone (2022), we use NDVI in the peak forage months identified in Strategy 1 above and perform regression analysis of observed NDVI versus intervals according to Equation 1 below:

$$N_{gpt} = \beta_0 + \beta_1 RI_{gkt} + \beta_2 RI_{glt} \tag{1}$$

where N_{gpt} is the average NDVI value for the peak (p) forage months, and RI is the rainfall index in grid (g) for two intervals (k, l) that follow the non-consecutive participation rule in year (t) that have the largest impact on peak forage production on the basis of β parameters estimated. Equation 1 is thus repeatedly estimated over the 30-year period for the three identified grids using combinations of different k and l intervals, ultimately leading to interval choices with the largest and statistically significant ($P \leq 0.05$) β_1 and β_2 estimates.

The third strategy, termed Basis Risk Leveraging, is the most data-intensive and selects intervals that reduce negative basis risk while simultaneously increasing positive basis risk. Figures 4 and 5 help demonstrate the concept by highlighting the potential for false negative and false positive payments. As the concept suggests, there are instances where farmers experience forage loss and would ideally receive a payment. However, the average rainfall across the grid may not be sufficiently low to trigger a payment, resulting in a false negative. Conversely, a producer may experience good forage production due to their specific location within a grid, yet the average rainfall in the grid may be low enough to trigger a payment, illustrating a false positive. Following Keller and Saitone (2022) and Yu et al. (2019), we define the likelihood of the first scenario occurring as the False Negative Probability (FNP) and the likelihood of the second scenario as the False Positive Probability (FPP).

To select intervals using this strategy, we form an NDVI similar to the RI used by the Risk Management Agency to implement PRF as with the second strategy where NDVI was used to determine peak forage months. Assuming the chosen coverage level is 90%, a false negative event occurs if the RI is above 90 while the NDVI is below 90; similarly, a false positive event occurs when the RI is below 90 and the NDVI index is above 90. We again utilize a linear programming algorithm to find the intervals (now not limited to two intervals as with the second strategy) that best balance these two outcomes seeking to minimize FNP and to maximize FPP while simultaneously determining the percent of value that should be assigned to each interval. Figures 4 and 5 demonstrate the average occurrence of these false negative and false positive events across the state. Additionally, Tables 1-3 show the intervals selected and the accompanying percent of production values assigned to each interval under each strategy for each of the three grid locations (Figure 2).

PRF versus No Coverage Analysis

With intervals and coverage levels selected as above, we now calculate the return/loss position for a forage producer in each grid. For each county, five years were chosen, representing different rainfall conditions: the driest year, the 25th percentile year, the median year, the 75th percentile year, and the wettest year in the data set covering 1994–2023. For every combination of year, county, and producer strategy, the profit or loss per acre relative to their 30-year average outcome was calculated. This was done in three steps. First, we use the CBV for the specific county used in our scenario to calculate what the indemnity payment would have been for the grid interval and year:

$$Interval\ Indemnity = 1 - \frac{RI_{gkt}}{C} * (CBV * C * \%policy) \quad (2)$$

where RI_{gkt} is the RI value observed in the county grid g, interval k, and year t; C is the chosen coverage level; and $\%policy$ is the amount of production value assigned to that interval. Equation 2 thus shows how the indemnity for a selected interval is calculated if the RI falls below the selected coverage level.

Similarly, we use the CBV to determine the value of forage production in the year being analyzed. We use our NDVI to determine the percent of normal forage produced in the year, so for example, if our NDVI value is 0.9, this implies that forage production was 90% of normal production in that year. We can then use the CBV to determine the value of production in the grid and county that year according to Equation 3 below:

$$Forage\ (Loss|Gain)_{gpt} = CBV * N_{gpt} - CBV \quad (3)$$

where N_{gpt} is the normalized peak (p) NDVI value observed in county grid, interval, and year. The forage loss or forage gain value represents the difference between observed forage, calculated using the observed NDVI, and expected forage based on a 30-year historical average NDVI. Finally, the sum of the values of Equations 2 and 3 represent the total profit—the sum of profit from the sale of forage and the net return from PRF indemnity payments. For simplicity, we assume hay production with a single cutting in a given year. Similar analysis can be used to explore multiple cuttings or pasture forage as well.

RESULTS

We present the results of our analysis to determine the profitability of PRF under several key scenarios. We turn first to the results in Table 4 for Boone County, the historically low rainfall county. This table shows example calculations and offers insight into what drives the results for this and other counties. Table 4 also shows the calculations for two years: 2005, the year with the lowest state average rainfall, and 2009, the wettest year among the study years in the state. For the driest year, all strategies, including the no-enrollment strategy, yielded some return from the value of the production of forage[vi].

Two of the three PRF enrollment strategies yielded higher profits compared to the no-enrollment strategy. The Near Peak Forage Months and the Peak Forage Protection strategies generated indemnities (due to low rainfall in the selected intervals) that exceeded premium costs by $35/acre and $34/acre, respectively, resulting in greater overall profit relative to no enrollment. However, the basis leveraging strategy yielded indemnities that were $9/acre less than premium costs, which reduced profitability relative to no enrollment.

The results in Table 4 highlight a key finding that will be useful for some of our results in the other tables, where basis risk is possible. Shown in Table 4's right-most column, using Basis Risk Leveraging, our calculations suggest that wet years are particularly susceptible to basis risk, perhaps due to excess rainfall creating poor conditions for forage production and harvest. PRF being single-peril coverage does not provide payment for forage loss when RIs are above the trigger threshold under these conditions.

Averaged over more weather years than the two weather years shown in Table 4, Table 5 demonstrates that each enrollment strategy performed better than no enrollment in Boone County. For Boone County, Peak Forage Protection was the best-performing strategy ,with a nearly 600% increase in per acre profit, while the Basis Risk Leverage strategy was the least profitable of the enrollment strategies. However, the Basis Risk Leverage strategy outperformed the no-enrollment strategy by $.70/acre in Boone County.

The results of our profit calculations for Lee County with median rainfall (Table 6) shows that enrolling in PRF was once again more profitable than no enrollment. Across the three enrollment strategies, there was an over 300% increase in profit per acre using the Basis Risk Leveraging strategy. Using that strategy, only one year was not profitable, while for the other years, indemnity payments more than covered premium payments and potential forage loss. Also, our calculations show that across the three enrollment strategies, in the drier years of 2005, 2007, and the average rainfall year of 2016, only the Peak Forage Protection strategy, in 2005 did not trigger an indemnity payment.

In contrast with the other counties, Polk County, the one with the highest precipitation in Arkansas during the 30-year weather range in our study, did not result in PRF enrollment strategies to be clear winners (Table 7). Looking at the average outcomes across the five scenario years, it shows that only one of the strategies, the Near Peak Forage Months strategy, is more profitable than not enrolling in PRF at all. As highlighted in Table 4 the driving factor was due to basis risk in high precipitation years that resulted in forage loss where PRF indemnities would not be triggered. With PRF covering only rainfall and not claim-by-claim forage loss, this caused the other two strategies of enrolling in PRF to be worse than not enrolling at all. This indeed does suggest a potential weakness of the program for wetter areas and warrants further study.

Overall, our results suggest that despite low loss ratios reported in the RMA summary of business data, several cases exist where profitable use of PRF is possible in the state across multiple rainfall year scenarios. However, our results also seem to confirm the suggestion that PRF may not perform as well in wetter areas, with Polk County, the wettest county in the state, showing that the profitability of enrollment relative to not enrolling in PRF was heavily dependent on the strategy used, and even then, only a minority of strategies proved profitable. This case warrants further study of PRF in the state. Nevertheless, we find a wide range of profitable county cases likely exist, and further grid-level analysis may be useful for producers in areas where PRF would likely be beneficial to their operation.

CONCLUSION

This study was conducted to understand how profitable PRF is in the state of Arkansas, a low-enrollment, wetter state. Low loss ratios and anecdotes of PRF not being useful in wetter areas likely contribute to low uptake of PRF at the state level, and this study shows that the performance of PRF insurance was not uniform across all counties in the state. Across the three counties studied, though, one of the most significant findings was the observation of lower-than-expected losses in Arkansas compared to the loss ratios reported via the RMA Summary of Business data. Producers in the Delta region, including Arkansas, have historically seen loss ratios below 1, meaning they often pay more in premiums than they receive in their indemnity payments. However, this study shows that cases exist for profitable use of PRF across multiple-year scenarios.

The result potentially suggests that low loss ratios may be the result of producers who have used PRF insurance for only a short time or inconsistently across years, since the potential exists for a negative outcome in any given year, but averaged over multiple years, the insurance plan shows positive performance in most areas. Also, newer participants may lack the historical data and understanding needed to select optimal intervals, leading to poor alignment of insurance coverage and actual forage loss. Farmers who frequently change their coverage intervals from year to year may also see reduced payouts. This inconsistency can lead to missed payments during key periods, especially in regions like Arkansas where rainfall is relatively stable but still subject to unpredictable variations.

Consistent with common anecdotes, our results show that PRF performed best in low and median precipitation counties across all strategies, given consistent yearly enrollment interval selection in those years. However, our results also suggest that wet counties/areas may be exposed to additional risk of enrolling in the program perhaps due to forage loss in excessively wet years and the single-peril nature of PRF. Such a result may give some producers pause, leading them not to enroll in the program in particularly wet counties.

The results of this study emphasize the importance of tailored PRF interval selection, particularly in regions like Arkansas with its diverse rainfall patterns. As such, decision-support software that could assist with picking intervals and production value coverage, as outlined for three different strategies for three grids in this article, may help farmers make more informed decisions about their insurance policies. With forage protection, improved economic outcomes and enhanced protection against forage losses appear attainable. Meanwhile, policymakers must consider the need for region-specific adjustments to PRF structures to better serve the needs of agricultural producers in the Delta region.

Furthermore, it is worth noting that our profits/losses calculations are on an unsubsidized, per acre basis. However, at the 90% coverage level used in this study, there is a 51% subsidy on the per acre premium rate, meaning producers using PRF only pay 49% (Mitchell and Biram, 2023). With subsidized premiums in mind, it presents an even stronger case that enrolling in PRF is likely profitable, particularly in the drier counties in Arkansas. Nevertheless, our results present rich opportunities for further investigation into this subject in the state and region.

FOOTNOTES

1 Traditional FCIP policies designed for annual row crop production require an assessment of yields at the end of the production period compared to yield potential, which can be difficult to assess, particularly when forage is grazed as stocking rates can impact regrowth potential.

2 When first introduced, PRF was based on a vegetation index in some states and a rainfall index in other states. With updates to the program in 2016, PRF plans in all states were converted to a rainfall index. Additionally, the program began to offer separate coverage for irrigated and non-irrigated haying practices (Belasco and Hungerford, 2018).

3 The coverage level is like the deductible common in most other insurance policies. For example, if a producer selects a 90% coverage level, it is like selecting a 10% deductible in other insurance policies, and the program begins to pay on the portions of losses more than 10% of the insured value.

4 Representative grid rainfall is categorized according to their 30-year normal rainfall levels. County representative grids were selected based on the highest, lowest, and mean 30-year normal values.

5 The RMA reports the county base values https://public-rma.fpac.usda.gov/apps/PRF. The county base value is the county/region monetary representation of the forage grown, differing whether the acreage is covered for hay or grazing land.

6 NDVI_I suggest a 10% forage gain, which we represent as excess profit of $19.48 based on the county base value of forage.

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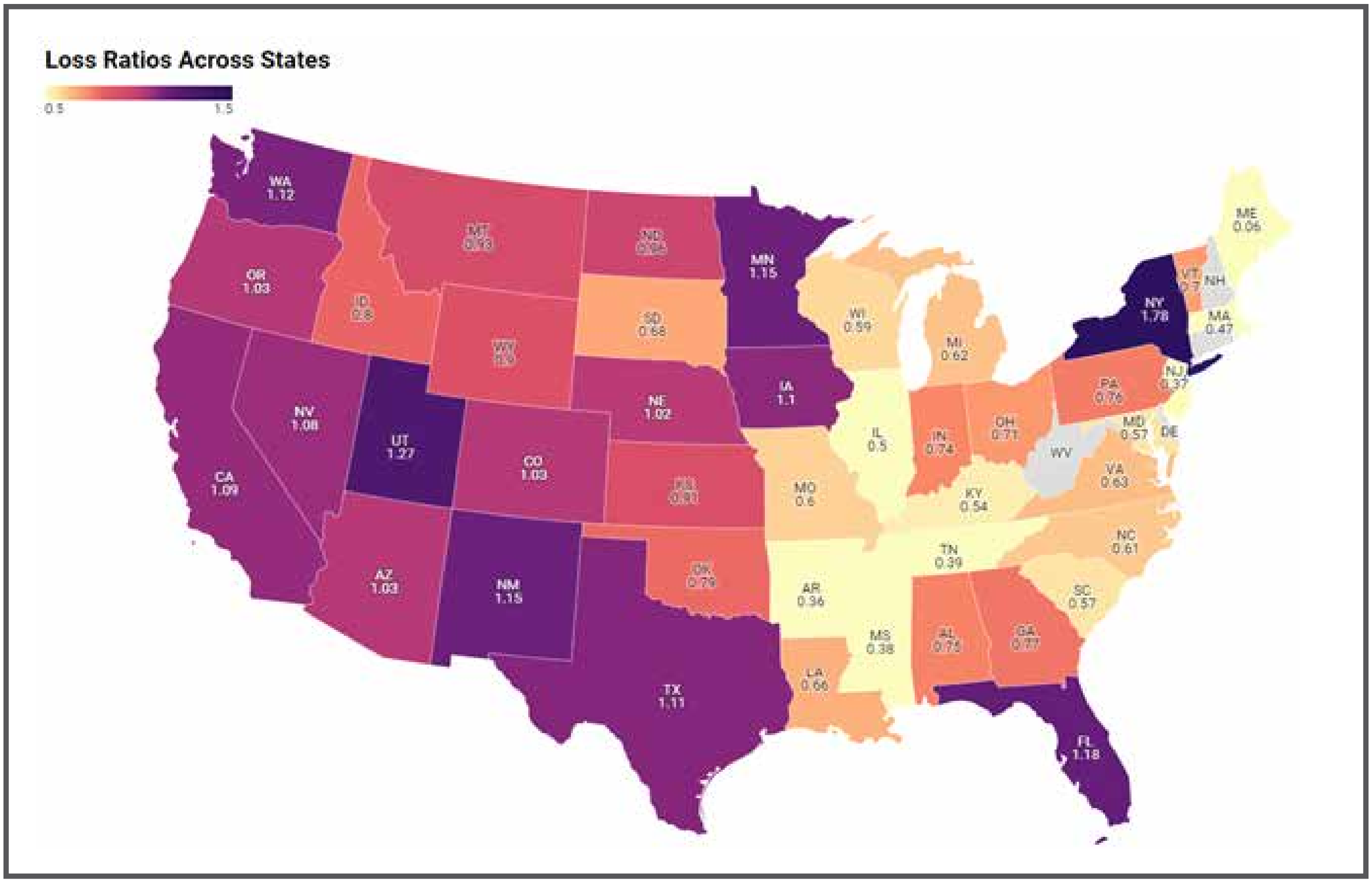

Figure 1. PRF loss ratios by state, 2018–2023

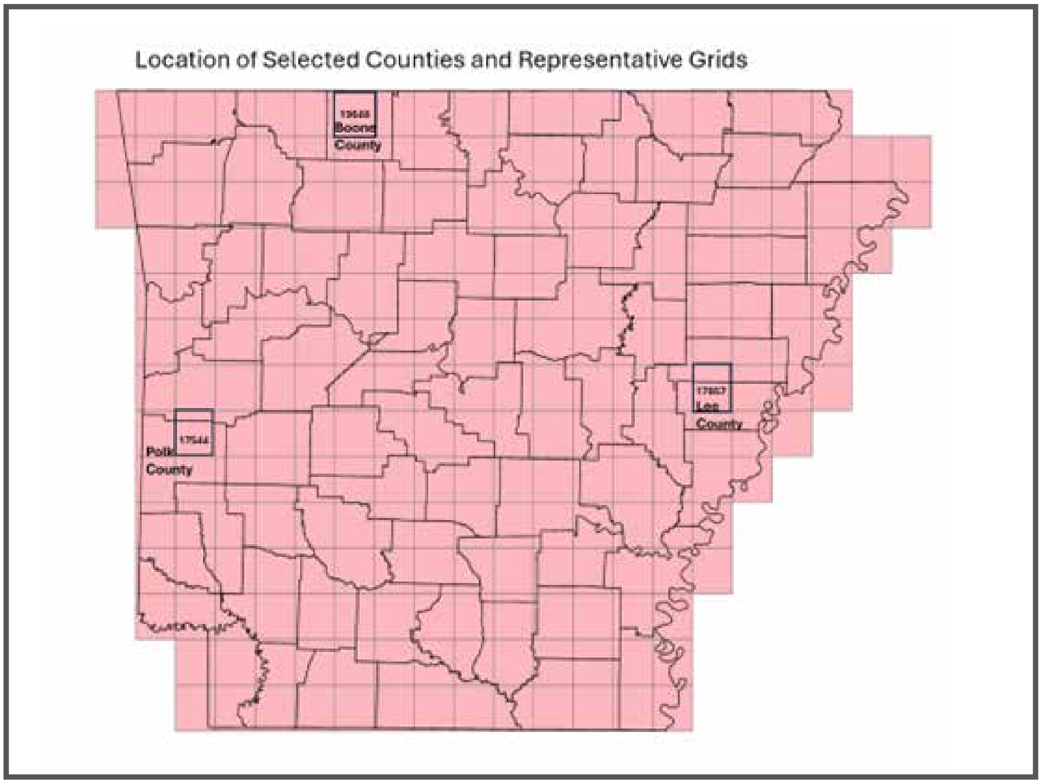

Figure 2. Selected counties and their representative grids, showcasing their geographical location in the state, where Boone County has the lowest 30-year average rainfall, Polk County has the highest 30-year average rainfall, and Lee County has the median 30-year average rainfall

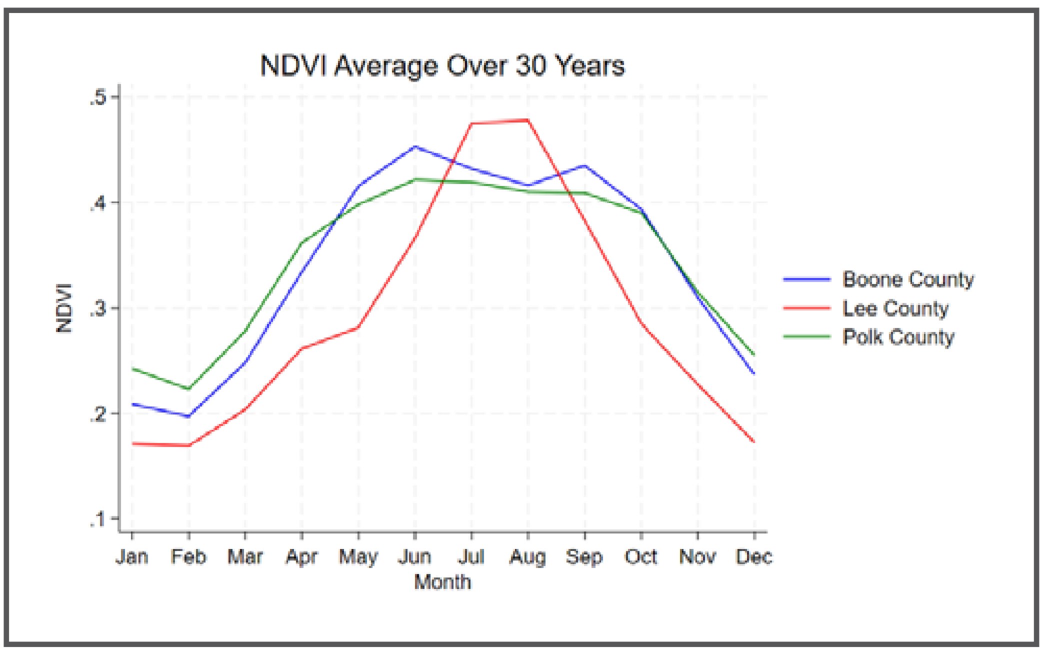

Figure 3. 30-year average Normalized Difference Vegetation Index (NDVI) values for Boone, Lee, and Polk Counties, where Boone County has the lowest 30-year average rainfall, Polk County has the highest 30-year average rainfall, and Lee County has the median 30-year average rainfall

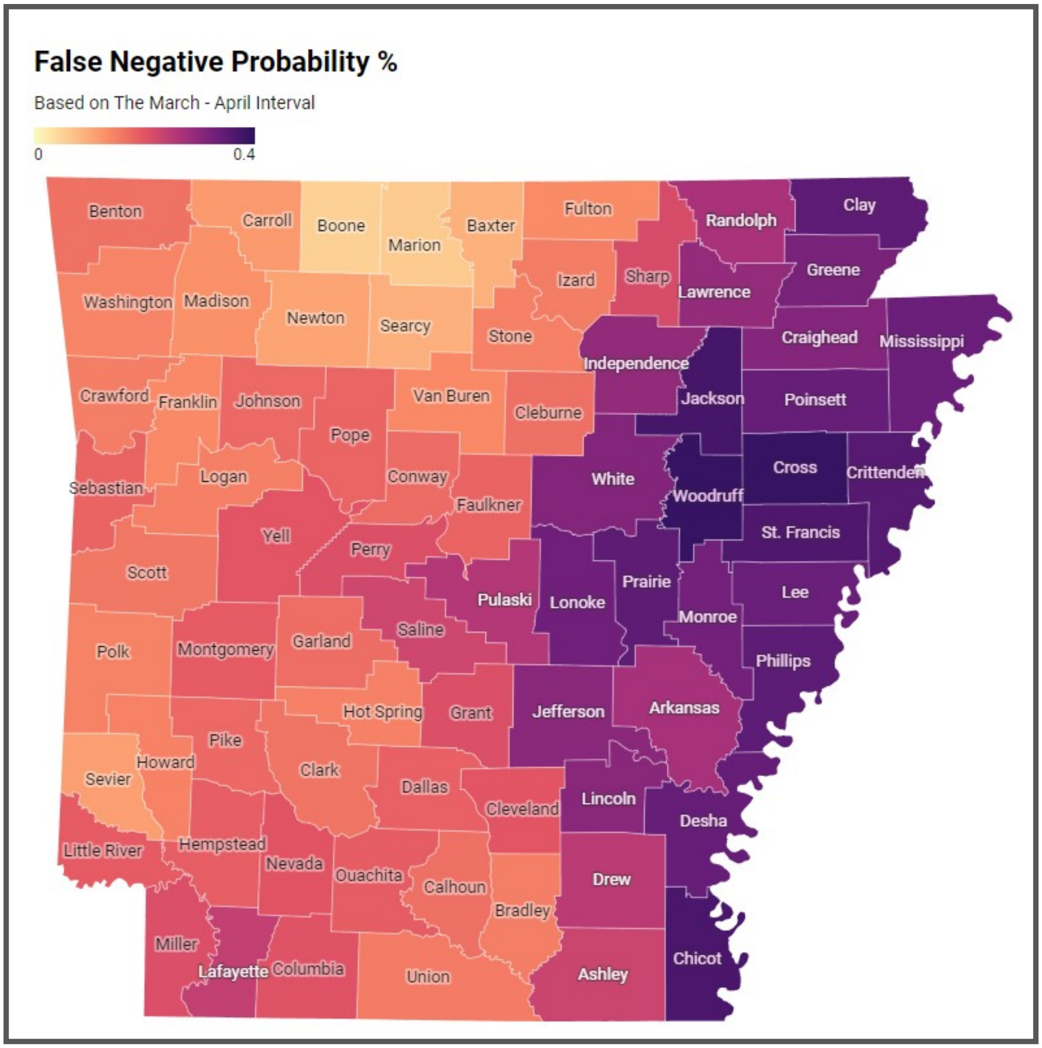

Figure 4. Degree of false-negative outcomes (not getting an indemnity when actual loss occurred) across Arkansas counties if covered by the March-April interval (notes: the March-April interval was found to be the most impactful with peak forage production (June-July) in the state using Equation 1)

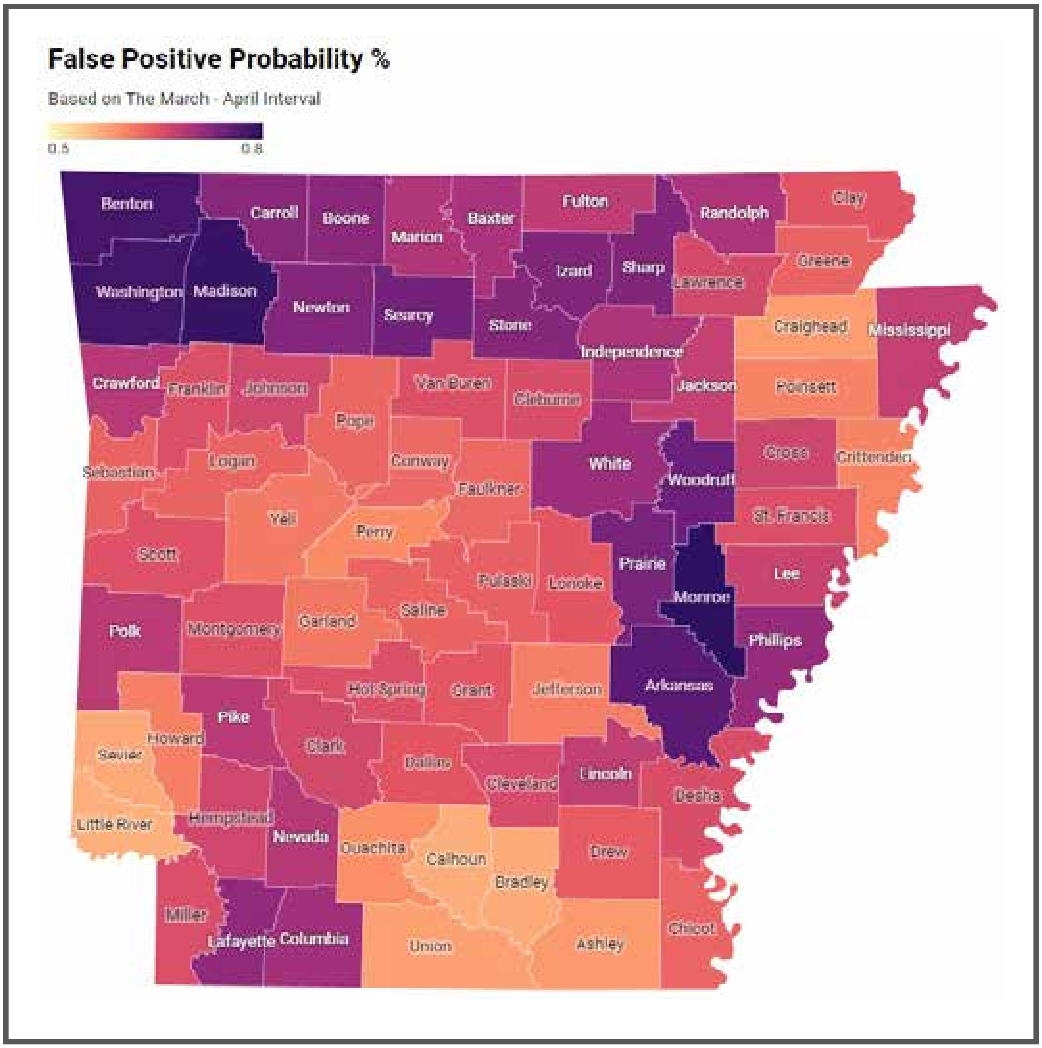

Figure 5. Degree of false-positive outcomes (getting an indemnity when no losses occurred) across Arkansas counties if covered by the March-April interval (note: the March-April interval was found to be the most correlated with peak forage production (June-July) in the state using Equation 1)

Table 1. Optimal Intervals and Interval Percentage of Production Selections for Three Selection Strategies in Boone County with Least Recorded Rainfall across Arkansas, 1994–2023*

Interval	Near Peak Forage Months	Peak Forage Protection	Basis Risk Leveraging
(2) Feb-Mar	0%	**60%**	**60%**
(5) May-Jun	**50%**	**40%**	0%
(7) Jul-Aug	**50%**	0%	0%
(8) Aug-Sep	0%	0%	**40%**
Total Policy %	**100%**	**100%**	**100%**

*This table shows the percentage of a PRF-RI policy that should be insured in each interval based on assigned weights from consumer profiles in Boone County Arkansas. The grid that represents this county is 19648. The intervals are numbered 1 = Jan-Feb to 11 = Nov-Dec, and intervals with 0% values were removed to conserve space.

Table 2. Optimal Intervals and Interval Percentage of Production Selections for Three Selection Strategies in Lee County with Median Recorded Rainfall across Arkansas, 1994–2023*

Interval	Near Peak Forage Months	Peak Forage Protection	Basis Risk Leveraging
(2) Feb-Mar	0%	**40%**	0%
(5) May-Jun	**50%**	0%	**12%**
(6) Jun-Jul	0%	**60%**	0%
(7) Jul-Aug	**50%**	0%	**28%**
(9) Sep-Oct	0%	0%	60%
Total Policy %	**100%**	**100%**	**100%**

*This table shows the percentage of a PRF-RI policy that should be insured in each interval based on assigned weights from consumer profiles in Lee County Arkansas. The grid that represents this county is 17857. The intervals are numbered 1 = Jan-Feb to 11 = Nov-Dec, and intervals with 0% values were removed to conserve space.

Table 3. Optimal Intervals and Interval Percentage of Production Selections for Three Selection Strategies in Polk County with Most Recorded Rainfall across Arkansas, 1994–2023*

Interval	Near Peak Forage Months	Peak Forage Protection	Basis Risk Leveraging
(4) Apr-May	0%	**60%**	0%
(5) May-Jun	**50%**	0%	0%
(7) Jul-Aug	**50%**	0%	**60%**
(10) Oct-Nov	0%	**40%**	**40%**
Total Policy %	**100%**	**100%**	**100%**

*This table shows the percentage of a PRF-RI policy that should be insured in each interval based on assigned weights from consumer profiles in Polk County Arkansas. The grid that represents this county is 17544. The intervals are numbered 1 = Jan-Feb to 11 = Nov-Dec, and intervals with 0% values were removed to conserve space.

Table 4. Financial Impact Calculation of PRF in Boone County (Low Precipitation County in Arkansas) for the Driest and Wettest Years, 1994–2023, on a per acre basis*

Year and Weather	2005 – Dry				2009 – Wet			
Strategy	**No Enrollment**	**Near Peak Forage Months**	**Peak Forage Protection**	**Basis Risk Leverage**	**No Enrollment**	**Near Peak Forage Months**	**Peak Forage Protection**	**Basis Risk Leverage**
CBV	$188.00	$188.00	$188.00	$188.00	$188.00	$188.00	$188.00	$188.00
NDVI_I	1.10	1.10	1.10	1.10	0.99	0.99	0.99	0.99
Forage loss/ gain[a]	$19.48	$19.48	$19.48	$19.48	-$2.11	-$2.11	-$2.11	-$2.11
Premium	N/A	-$21.22	-$22.53	-$24.43	N/A	-$21.22	-$22.53	-$24.43
Indemnity	N/A	$56.96	$57.11[b]	$16.13	N/A	$0.00	$15.23	$15.23
Profit/Loss	**$19.48**	**$55.22**	**$54.06**	**$11.18**	**-$2.11**	**$23.33**	**-$9.41**	**-$11.31**

*Note: [a] The forage loss/gain is the forage recorded that year (NDVI_I *CBV) minus the historical average assigned to the county by the RMA (CBV) or $188*(1.1036 -1) = $19.48. [b] The indemnity in the 2005 Peak Forage Protection column, for example, was calculated as follows:

$$\left(1-\frac{75.7}{90}*(188*90\%*60\%)\right)+\left(1-\frac{35.5}{90}*(188*90\%*40\%)\right)=\$57.11,$$

where 75.7 was the RI for Feb-Mar (Table 1) and 35.5 was the RI for May-June (Table 1) in 2005 with all calculations assuming a 90% coverage level.

Table 5. Financial Impact of PRF in Boone County (Low Precipitation County in Arkansas) in Different Weather-Year Scenarios on a Per Acre Basis

Year & Weather	No Enrollment	Near Peak Forage Months	Peak Forage Protection	Basis Risk Leveraging
2005 – Dry	$19.48	$55.22	$54.06	$11.18
2007 – 25%	($35.39)	($23.39)	($6.39)	$6.61
2016 – Average	$26.73	$29.73	$52.73	$30.73
2011 – 75%	$3.28	($1.72)	($19.72)	($21.72)
2009 – Wet	($2.11)	($23.33)	($9.41)	($11.31)
Average Outcome	$2.40	$7.30	$14.25	$3.10

Table 6. Financial Impact of PRF in Lee County (Average Precipitation County in Arkansas) in Different Weather-Year Scenarios on a Per Acre Basis

Year & Weather	No Enrollment	Near Peak Forage Months	Peak Forage Protection	Basis Risk Leveraging
2005 – Dry	$2.98	$39.98	($5.02)	$34.98
2007 – 25%	($7.90)	$36.10	$36.10	$36.10
2016 – Average	$66.98	$59.98	$40.98	$106.98
2011 – 75%	($11.75)	($11.75)	$0.25	$6.25
2009 – Wet	($26.78)	($52.78)	($44.78)	($56.78)
Average Outcome	$4.71	$14.31	$5.51	$16.31

Table 7. Financial Impact of PRF in Polk County (High Precipitation County in Arkansas) in Different Weather-Year Scenarios on a Per Acre Basis

Year & Weather	No Enrollment	Near Peak Forage Months	Peak Forage Protection	Basis Risk Leveraging
2005 – Dry	($13.81)	$23.19	$24.19	$5.19
2007 – 25%	($48.23)	($57.23)	($59.23)	($49.23)
2016 – Average	$24.63	$29.63	$21.63	$19.63
2011 – 75%	$3.39	$1.39	($21.61)	$3.39
2009 – Wet	($10.33)	($34.33)	($35.33)	($37.33)
Average Outcome	($8.87)	($7.47)	($14.07)	($11.67)

Submission Guidelines

JOURNAL OF THE ASFMRA

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

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

OBJECTIVES

The objectives of the *Journal* are to:

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

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

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

AUTHOR GUIDELINES FOR SUBMITTING MANUSCRIPTS

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

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

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

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

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

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

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

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

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

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

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

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

12. **The Editorial Review Process.**

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

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

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

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

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

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

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

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

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