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Cash crops or cover crops? The reasons and barriers for adopting cover crops in the Southern Great Plains of Texas and Oklahoma

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Water conservation practices such as cover crop adoption have been promoted as effective strategies to improve water quality and soil health. However, cover crop adoption rates have remained low in Texas. A better understanding of the barriers to farmer cover crop adoption can highlight new pathways, encouraging conservation practice adoption across regions of the U.S. Our study examined reasons and barriers to cover crop adoption, including farmers' demographics and farm characteristics. Using guidance from social cognitive theory and the theory of social normative behavior, we also examined how personal, cognitive, and environmental factors shaped farmers' behaviors. The data collection process took place starting May 5, 2022, and ending December 30, 2022. A random sample of 3,000 participants was selected from the 88 counties in the Southern Great Plains of Texas and Oklahoma, using the 2021 USDA farm payment payees' online files. Data were collected using a cross-sectional survey to describe characteristics of farmer populations (e.g., farmers, ranchers, land managers). Results indicated adopters were largely 51–70 years old (58.3%), female (55.6%), and white (94.4%), with a majority being highly educated [i.e., having a graduate (22.2%) or bachelor's (36.1%) degree]. Moreover, adoption reasons increased as farmers attained smaller income amounts from agricultural products. Of farmers who adopted cover crops, 38.9% did not use irrigation while 22.2% irrigated between 81 and 100% of their farmed land. Most adopters (61.8%) farmed annual crops. Adopters and non-adopters were significantly different in their environmental and economic barrier perceptions for cover crop adoption. We conclude by discussing situational and economic factors driving these findings and providing opportunities for future research.

KEYWORDS

water conservation practices, regenerative agriculture, soil health, sustainability, drought

1 Introduction

As the largest consumer of water globally, agriculture is vulnerable to water resource availability (Caparas et al., 2021). The need to produce enough food for growing populations while conserving potable water is an urgent global issue (Caparas et al., 2021), particularly as global water scarcity is predicted to increase due to climate change (Hanjra and Qureshi, 2010). Thus, water use, water quality, and water conservation are relevant to all food systems (Basara et al., 2013). As demands to produce more food with fewer resources increase (Pittelkow et al., 2015; Thompson et al., 2021), farmers have been encouraged to evaluate their land management practices (Thompson et al., 2021), including the adoption of more efficient soil and water conservation practices.

The demand for agriculture and human water resource consumption, along with population growth, has steadily increased in the U.S. Southern Great Plains region (Basara et al., 2013). This region has also experienced persistent extreme drought conditions since 2011 (National Integrated Drought Information System, 2023), impacting many sectors of the agriculture industry (Steiner et al., 2017) and contributing to crop failure, livestock feed shortages (Steiner et al., 2017; Zhou et al., 2017), wildfires, and generational farm and ranch closures (National Integrated Drought Information System, 2023). Therefore, it is critically important for farmers in the Southern Great Plains region and those reliant on food and other agricultural products in this area to understand how to manage and conserve water and soil health (Basara et al., 2013).

One effective approach to conserve water and improve soil health is the use of cover crops. Cover cropping is a practice of planting green cover between planting and harvesting cash crops, which protects the soil's surface rather than leaving farmland bare (Singh et al., 2020; Wang et al., 2021b). Cover crops contribute to improved soil fertility and structure, suppressed weeds, reduced pest pressure (Plastina et al., 2020; Wallander et al., 2021; Wang et al., 2021b), enhanced soil resilience, improved water quality (Myers and LaRose, 2022; Wang et al., 2021b), decreased erosion and nutrient and moisture loss (Myers and LaRose, 2022; Saleem et al., 2020; Singh et al., 2020), increased water infiltration and storage (Koudahe et al., 2022), amplified carbon sequestration through soil storage, and reduced atmospheric CO₂ (Lal, 2004).

Additionally, cover crop adoption benefits are dependent on management practices (Nielsen et al., 2005), access to water and irrigation, and environmental factors such as soil type and evapotranspiration (Ghimire et al., 2018). Therefore, farmers in the Southern Great Plains region may be hesitant to adopt cover crops if they are unfamiliar with proper cover crop implementation practices for semi-arid areas (Ghimire et al., 2018). Numerous conservation programs offer financial assistance at federal and state levels for water conservation (Plastina et al., 2020), allocating billions of dollars each year to enhance conservation practices (Claassen and Ribaudo, 2006). As more farmers have learned about cover crop implementation benefits, adoption rates have increased (up to 11% of farms across the Southern Great Plains region; Wang et al., 2021b). Yet, cover crop adoption rates remain low across the U.S. (Thompson et al., 2021).

The Natural Resource Conservation Service (NRCS) and the U.S. Department of Agriculture (USDA) have also used cover crops to develop key principles that enhance best management practices (BMPs) for farmers: minimizing soil disturbance and maximizing soil cover, biodiversity, and the presence of living roots (Wallander et al., 2021). These BMPs aim to improve environmental resources while

increasing agricultural production (Denny et al., 2019; Thompson et al., 2021). Research on BMPs is also expanding (Dessart et al., 2019), with scholars arguing that it is imperative to identify factors influencing farmers' adoption of cover crop practices (Carlisle, 2016; Prokopy et al., 2008).

Some demographic factors regularly included in BMP adoption studies are important adoption predictors as well (Prokopy et al., 2019). Prior research has stated that farmer demographics, including age, gender (Asfaw and Neka, 2017; Wang et al., 2021a), and household characteristics (Barbercheck et al., 2014; Mango et al., 2017), can be indicators of cover crop adoption (Mango et al., 2017; Prokopy et al., 2019). Age is a predictor that regularly impacts BMP adoption (Knowler and Bradshaw, 2007; Prokopy et al., 2019), with younger farmers being more likely to adopt BMPs due to having longer planning horizons (Barbercheck et al., 2014; Baumgart-Getz et al., 2012). Gender has been associated with cover crop adoption (Asfaw and Neka, 2017; Wang et al., 2021a,b) though this association is complicated by demographic trends with a majority of U.S. farmland now being owned by women (Whitt and Todd, 2021). Indeed, women are the most rapidly growing group of farm operators in the U.S. (Barbercheck et al., 2014). This may indicate a growing role for women in agriculture, or it could be that increasing numbers of women in agriculture have also increased the likelihood women adopt cover crop practices (Wang et al., 2021b). Lastly, household characteristics also impact cover crop adoption (Barbercheck et al., 2014; Mango et al., 2017). Barbercheck et al. (2014) found that household characteristics like the number of people in a household and future farm plans were shown to increase adoption.

Farmland characteristics and management may also affect cover crop adoption (Wang et al., 2021b; Sarrantonio and Gallandt, 2003). Such characteristics include scale (Barbercheck et al., 2014; Knowler and Bradshaw, 2007; Prokopy et al., 2019; Wang et al., 2021a), type and diversity of products, agricultural economy and markets, topography and landscape characteristics, labor demands, ownership structure (Barbercheck et al., 2014; Wang et al., 2021a), and livestock ownership and diversity (Knowler and Bradshaw, 2007; Wang et al., 2021a). Moreover, the stated farm characteristics, existing farm management practices, and potential to increase income are simultaneously considered when considering cover crop adoption (Wang et al., 2021a).

Furthermore, farmers often make cover crop-related business decisions that require large investments, long-term commitments, and have economic consequences (Dessart et al., 2019). As a result, the financial constraints and economic uncertainty of cover crops' long-term benefits can affect farmers' decisions even if benefits outweigh costs (Bowman et al., 2016; Campbell et al., 2021), creating cognitive lock-in with financial constraints, where established norms with current practices prevent suitable new practice adoptions (Wald et al., 2025). In prior research, farmers indicated financial barriers as the most prominent barriers to adoption (e.g., Duke et al., 2022; Carlisle, 2016) with specific barriers including return on investment, input cost, labor cost, and equipment requirements (Roesch-McNally et al., 2017; Duke et al., 2022; Kissel et al., 2023). Decisions to adopt cover crops can also depend on the state of the agricultural economy (Prokopy et al., 2019), and decision-making authority has the potential to influence cover crop adoption (Barbercheck et al., 2014).

Information access through educational events (e.g., field days, conferences, and demonstration sites) and access to technology can influence farmers' decisions to adopt cover crop practices (Arbuckle and

Roesch-McNally, 2015; Plastina et al., 2020; Prokopy et al., 2008; Wang et al., 2021b) by raising awareness of the technology (Prokopy et al., 2008). Those who adopt cover crops believe an emphasis should be placed on educating farmers and agricultural advisors about adoption benefits to enact more cost-effective and ecologically conscious land management practices (Arbuckle and Roesch-McNally, 2015). Addressing the need for education, Extension training is important as farmers' perceptions of cover crop economics are likely to improve through training facilitated by university Extension educators (Wang et al., 2021b; Kissel et al., 2023). Farmers who receive support from Extension agencies addressing cover crop adoption benefits and barriers are more likely to adopt the practice (Arbuckle and Roesch-McNally, 2015).

Farmers' decisions to adopt cover crop practices are also often influenced by their beliefs about land stewardship (Thompson et al., 2021; Denny et al., 2019; Baumgart-Getz et al., 2012; Adusumilli and Wang, 2018; Prokopy et al., 2019). These beliefs are positively correlated with land stewardship attitudes, environmental awareness (Baumgart-Getz et al., 2012; Knowler and Bradshaw, 2007), and BMP adoption (Prokopy et al., 2019; Adusumilli and Wang, 2018). Farmers' concerns for environmental consequences from agricultural production also influence the likelihood of adoption (Barbercheck et al., 2014). Farmers' beliefs and social-psychological characteristics can influence their land management practices (Baumgart-Getz et al., 2012; Clark and Lowe, 1992; Battershill and Gilg, 1997) and decision-making. In areas where stewardship practices are the norm, farmers also identify a compromise between private and collective overhead costs as the right thing to do (Baumgart-Getz et al., 2012). Therefore, farmers who are motivated by stewardship are more likely to adopt cover crops altruistically (Thompson et al., 2021). As land stewardship attitudes become more favorable, the number of BMPs farmers adopt increases (Denny et al., 2019). However, altruistic motivations alone

are unlikely to motivate widespread adoption (Thompson et al., 2021). For example, Lee et al. (2018) found farmers with low levels of perceived agronomic capacity to implement conservation practices had a lower likelihood of adopting cover crops.

To examine how our study's identified factors influence cover crop adoption, we draw from social cognitive theory (SCT) and the theory of normative social behavior (TNSB). SCT suggests it is critical to understand the influence of social determinants on behavioral change (Phipps et al., 2013; Luszczynska and Schwarzer, 2015). Thus, our study uses SCT to understand and examine farmers' reasons for cover crop adoption. This approach can help explain farmers' perceived barriers and factors associated with cover crop adoption by drawing connections between farmer characteristics and cover crop adoption. This is done by observing a farmer's belief in their ability to enact adoption (i.e., self-efficacy) and examining how this belief is associated with their expected consequences of adoption, personal goals, social-cultural values and identities, and adoption behaviors (Bandura, 1997; Luszczynska and Schwarzer, 2015). SCT can also provide insight into Extension efforts that can support farmers' cover crop adoption practices by connecting education and engagement strategies with farmers' behavioral change goals and social-cultural values and identities (e.g., family values, gender identities, educational level, and attitudes) (see Figure 1).

Beyond the extension of SCT, our study uses the theory of normative social behavior (TNSB; Rimal and Real, 2005) to examine farmers' adoption of cover crops. The TNSB posits that cognitive mechanisms, including group identity, outcome expectations, and injunctive norms, moderate and mediate the relationship between descriptive norms and behaviors (Rimal, 2008; Rimal and Real, 2005; Carcioppolo et al., 2017). TNSB defines social norms as a function of interpersonal, behavioral communication amongst a

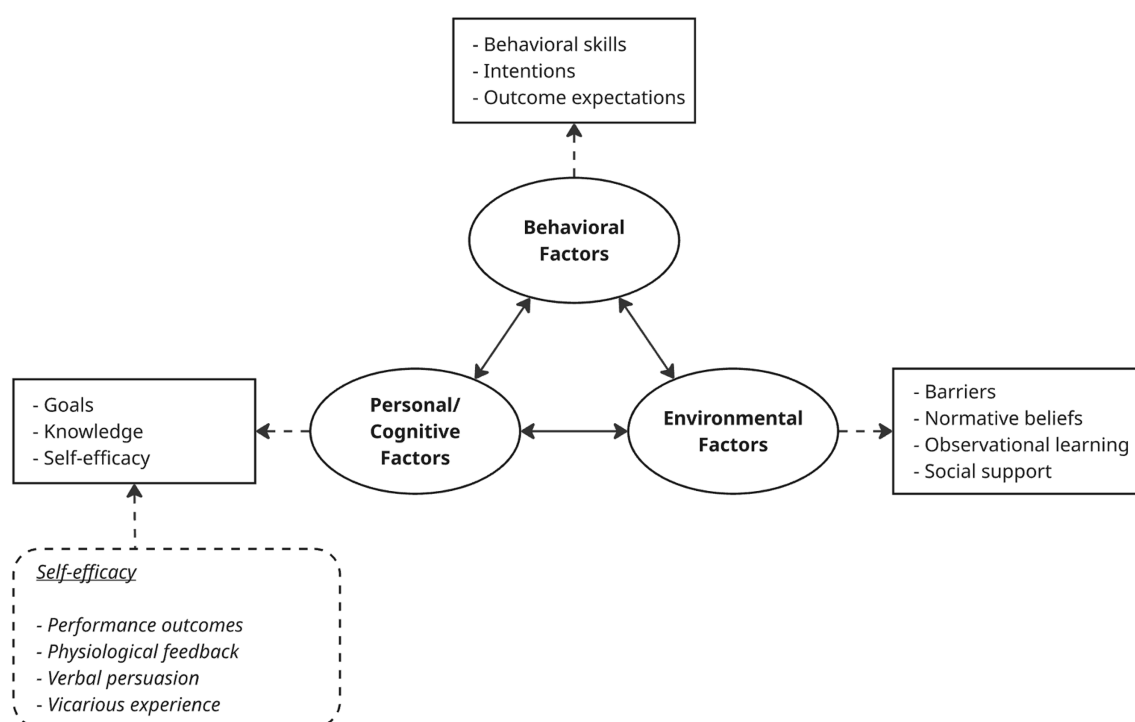


FIGURE 1
Bandura's (1997) social cognitive theory model.

group of individuals (Lapinski and Rimal, 2005; Hogg and Reid, 2006). The theory addresses the communicative nature of social normative belief development through perceptions of social normative behaviors (Lapinski and Rimal, 2005). This allows normative perceptions to be influenced in terms of individuals' beliefs and prevention behaviors, which are shared and reflected amongst a community or group of individuals (Lapinski and Rimal, 2005). The main premise of TNSB is its relationship between descriptive norms and behavior and the moderating perceptual variables of ego involvement, perceptions of injunctive norms, group identity, and outcome expectations. This theory applies well to our study's context because previous work suggests farmers' adoption behaviors are motivated by their normative perceptions of water conservation farming practices, social networks, farm demographics, educational opportunities, and financial factors. Understanding farmers' goals for their specific environmental, social, and economic contexts can help address regional policies, outreach, and adoption strategies (Lavoie et al., 2021).

As a result, the current study uses both social cognitive theory (SCT) and the theory of normative social behavior (TNSB) to identify differences associated with farmers' perceived barriers and reasons for adopting cover crop practices. In addition, we seek to answer the following research questions: what are the personal and farm characteristics of farmers who adopted cover crops; what are farmers' perceived reasons for adopting cover crops; and what barriers are associated with farmers' decision not to adopt cover crops? Throughout this article, we refer to farmers, ranchers, and land managers as 'farmers.' Detailed information on these farmers can be found in Tables 1–3. Our study informs practical efforts by policymakers, extension educators, and resource managers to encourage adoption and identify new ways to engage with farmers about the perceived barriers and potential benefits of conservation practices like cover crop adoption.

2 Materials and methods

2.1 Study design

We conducted the current study using a quantitative survey. A cross-sectional survey research design was most suitable because we aimed to describe population characteristics (Fraenkel et al., 2019). A mailed paper survey was used because farmer populations can be difficult to reach via electronic means (Jensen et al., 2007). Our study was part of a larger research project, but here we report only the data relevant to cover crop adoption.

2.2 Population and sample

The population for our study was the 2021 USDA farm payment payees from the 88 counties in the Southern Great Plains of Texas and Oklahoma, which we selected from the USDA online payment files. We collected a random sample of 1,500 addresses for each round (two rounds total) of data collection for 3,000 potential participants. We had 194 survey responses, but not all individuals responded to each survey question. We removed 117 respondents from the dataset due to missing data, leaving 77 usable responses. Although postal surveys are preferred over email for farmers (Zahl-Thanem et al., 2021), low response rates

TABLE 1 The socio-demographic characteristics of survey participants (N = 77).

Characteristic	n	%
Age		
31–50 years	11	14.3
51–70 years	43	55.8
71+ years	23	29.9
Gender		
Female	44	57.1
Male	33	42.9
Highest level of school		
Less than high school	1	1.3
High school graduate	9	11.7
Some college	17	22.1
Associate degree	11	14.3
Bachelor's degree	25	32.0
Graduate degree	14	18.0
Percentage of income from agriculture		
0%	3	3.0
1–20%	24	31.2
21–40%	8	10.4
41–60%	12	15.6
61–80%	11	14.3
81–100%	19	24.7
Ethnicity		
American Indian or Alaskan Native	0	0.0
Black or African American	0	0.0
Spanish Hispanic or Latino	4	5.2
White	71	92.2

The total percentages are not 100% for every *n* due to rounding. Some respondents did not report their ethnicity; therefore, ethnicity does not add up to 77 (*n* = 75), nor does the total percentage add up to 100%.

are typical when surveying farmers because many farmers do not respond to research surveys in general (Pennings et al., 2002).

Most of the participants were over the age of 50 (*n* = 66; 85.7%), with 57.1% being female (*n* = 44), 32% having a bachelor's degree (*n* = 25), and 31.2% reporting 1–20% of their income was generated from agriculture (*n* = 24). An overwhelming majority of the participants identified as White (*n* = 71; 92.2%; Table 1).

2.3 Instrument development

Participants agreed to participate via a consent form prior to the study. After stating they were at least 18 years old, participants continued to the survey questions. We measured the personal factors, including characteristics of farmers who adopted cover crops using five items: (1) *which age range do you fall into*; (2) *what is your gender*; (3) *what is your ethnicity*; (4) *what is the highest level of education you have completed*; and (5) *approximately what percentage of your household income comes from agricultural production*? Participants

TABLE 2 The crosstabulation of survey participants who did and did not adopt cover crops (responded “Yes” or “No” to adoption, Yes, $n = 36$; No, $n = 41$).

Characteristic	Did not adopt		Did adopt	
	n	%	n	%
Age				
31–50	6	14.6	5	13.9
51–70	22	53.7	21	58.3
71+ years	13	31.7	10	27.8
Gender				
Female	24	58.5	20	55.6
Male	17	41.5	16	44.4
Highest level of school				
Less than high school	1	2.4	0	0.0
High school graduate	4	9.8	5	13.9
Some college	12	29.3	5	13.9
Associate’s degree	6	14.3	5	13.9
Bachelor’s degree	12	29.3	13	36.0
Graduate degree	6	14.6	8	22.0
Percentage of income from agriculture				
0%	1	2.4	2	5.6
1–20%	15	36.6	9	25.0
21–40%	4	9.8	4	11.1
41–60%	8	19.5	4	11.1
61–80%	7	17.1	4	11.1
81–100%	6	14.6	13	36.1
Ethnicity				
American Indian or Alaskan Native	0	0.0	0	0.0
Black or African American	0	0.0	0	0.0
Spanish Hispanic or Latino	2	4.9	2	5.6
White	37	90.2	34	94.4

The total percentages are not 100 for every characteristic due to rounding. Total n does not add up to the total respondent amount for ethnicity due to some respondents opting out of reporting it.

responded to each item by selecting the multiple-choice option reflective of their personal characteristics.

Cognitive factors, or farmers’ beliefs about cover crop adoption, were measured using two scales adapted from [Carlisle’s \(2016\)](#) study. The first scale was a six-point Likert scale ranging from “Strongly agree” to “Strongly disagree.” The scale was developed into three sections, including economic, education, and personal beliefs. Each section contained seven Likert scale item statements and one open response prompt to capture other potential reasons not listed. The second scale contained the open-ended response question: *What are other reasons that you believe farmers use cover crops in your area?*

To examine environmental factors, we measured barriers associated with farmers’ decisions to adopt cover crops, farm characteristics, and financial issues. Barriers were measured using two six-point Likert scales that ranged from “Strongly agree” to “Strongly disagree.” These items were also adapted from [Carlisle \(2016\)](#). The first scale was

TABLE 3 The crosstabulation of survey participants who did and did not adopt cover crops (responded “Yes” or “No” to adoption) for total acres farmed and percent irrigated.

Characteristic	Did not adopt		Did adopt	
	n	%	n	%
Total acres farmed				
0–1,000	34	82.9	19	52.8
1,001–3,000	2	4.9	11	30.6
3,001+	5	12.2	6	16.7
Percentage of total acres irrigated				
0%	35	85.4	14	38.9
1–20%	2	4.9	7	19.4
21–40%	1	2.4	2	5.6
41–60%	2	4.9	5	13.9
61–80%	0	0.0	0	0.0
81–100%	1	2.4	8	22.2
Crop type				
Annual crops	25	37.3	47	61.8
Perennial forage	17	25.4	11	14.5
Small grains	22	32.8	17	22.4
Livestock	3	4.5	1	1.3
Years in agriculture				
3 years or less	18	43.9	18	50.0
3+ years	22	53.7	17	47.2

The total percentages are not 100 for every characteristic due to rounding. We visually analyzed these data to create the acreage ranges in this table. Reported acreages may include a summation across multiple farms, causing farmers to report seemingly larger acreage values for total acres farmed. For crop type, n values exceed 77 ($n = 143$) because some farmers reported having more than one crop type.

developed into three sections, including economics, education, and personal beliefs. Each section contained seven Likert-type scale item statements and one open response prompt—*other: please describe*. The second scale was developed into two sections, including farm characteristics and finance. The farm characteristics section contained 10 Likert scale questions and one open response prompt—*other: please describe*. The finance section contained six Likert scale item questions and one open response prompt—*other: please describe*.

2.4 Data collection

Data collection occurred between May 5 and December 30, 2022, using [Dillman et al.’s \(2014\)](#) tailored design method. We collected data in two rounds. For the first and second rounds of data collection, we received the addresses from the USDA through an open-access solicitation of the 2021 FSA online payment files.

We identified addresses within the scope of the study and randomly selected 3,000 addresses from the population using Excel. We selected addresses numbered 1–1,500 for the first round of the study and addresses numbered 1,501–3,000 for the second round of the study. Each round of the study included three versions of the survey (Survey A = 500, Survey B = 500, and Survey C = 500) for a total of 3,000 surveys sent across two rounds. We used modified data

collection methods and sent a pre-postcard to each of the 3,000 participants announcing the upcoming survey (Dillman et al., 2014). We sent the postcard on May 27, 2022, for the first round and December 2, 2022, for the second round. We sent the survey 7 days after sending the pre-survey postcard, the reminder postcard 14 days after, and the final survey 21 days after.

For round one, a total of 381 surveys were returned. Of those returned surveys, 83 were usable responses and 298 were unusable. We defined unusable responses as blank surveys or participants' failure to consent to the study. Due to the low response rate in round one, we initiated round two. Round two resulted in 501 responses, 111 of which were usable. The two rounds of survey distribution combined resulted in 194 returned responses. We entered survey responses into the Qualtrics database as they were returned. Surveys returned blank or with no answer to the survey consent form were counted toward the total response rate but not the usable response rate. This ensured the response rate accurately reflected the number of usable responses. Lastly, we removed 117 respondents from the dataset due to missing data, leaving us with 77 usable responses for data analysis. Respondents were removed from the dataset if one or more questions were unanswered for a given respondent's survey.

2.5 Validity and reliability

We conducted informal reviews by non-experts to establish face validity and obtained survey measures from prior research to establish content validity for our survey instrument. To assess internal consistency, we also calculated the Cronbach's Alpha scores for each variable derived from the survey instruments. We had the following adapted scales: Economic Reasons ($M = 3.28$, $SD = 0.76$, $\alpha = 0.65$), Prior Knowledge ($M = 3.01$, $SD = 0.95$, $\alpha = 0.89$), Personal Beliefs ($M = 2.24$, $SD = 0.75$, $\alpha = 0.82$), Economic Barriers ($M = 2.55$, $SD = 0.85$, $\alpha = 0.80$), Educational Barriers ($M = 2.94$, $SD = 1.11$, $\alpha = 0.92$), Farm Characteristic Barriers ($M = 3.08$, $SD = 0.97$, $\alpha = 0.72$), and Personal Belief Barriers ($M = 3.53$, $SD = 1.16$, $\alpha = 0.83$).

2.6 Data analysis

We analyzed these data through IBM SPSS Statistics to examine how farmer and farm characteristics (through crosstabulation), as well as reasons and barriers to adoption (through multivariate analyses of variance), could influence cover crop adoption. We then ran a power analysis for the combined dataset (survey groups A, B, and C) to ensure an adequate sample size and to substantiate having enough participants for reliable results. We conducted a crosstabulation in SPSS to analyze the demographic and farm characteristic data for research question one and an a-priori MANOVA: Global Effects power analysis from the F -test family for research question two with the following parameters: effect size $f^2(V)$: 0.2; α err prob.: 0.05; Power ($1 - \beta$ err prob): 0.8; number of groups: 2; and response variables: 3. We also conducted an a-priori MANOVA: Global Effects power analysis from the F -test family for research question three with the following parameters: effect size $f^2(V)$: 0.2; α err prob.: 0.05; Power ($1 - \beta$ err prob): 0.8; number of groups: 2; response variables: 5. Effect sizes used in cover crop-related research used Cohen's (1988) established effect sizes of 0.1 for small, 0.2 for moderate, and 0.3 for large

(e.g., Bryant et al., 2013). The number of participants needed to conduct research question two required at least 60 respondents, and 66 for research question three.

To answer research question one, we used a descriptive analysis via a crosstabulation. To answer research questions two and three and to identify the significant perceived reasons and barriers associated with adopting cover crop practices, we conducted regression analyses via a between-subjects single factorial multivariate analysis of variance (MANOVA). We coded the dependent variable (behavior) as "1" for adopting cover crops (1 = yes) and "2" for not adopting cover crops (2 = no). The independent variables were cognitive and environmental factors (i.e., personal belief, education, financial, and farm characteristic barriers). We also conducted regression analyses to examine the relationship between farmers' demographic characteristics and cover crop adoption, as well as farm characteristics and cover crop adoption. The independent variables were age, gender, ethnicity, education level, percentage of household income that comes from agricultural production, total acres farmed, percent of total acres irrigated, crop type, and farmer years in agriculture.

Qualitative data from open-ended survey questions were not analyzed for this article because the study's research questions were answered by analyzing our study's scale question data (as seen in Tables 1–3). Many qualitative responses were also left blank or marked as "N/A" (i.e., 75.1% of respondents for "What are other reasons that you believe farmers use cover crops in your area?" left a blank answer or stated "N/A"), making qualitative analyses challenging. Furthermore, our study did not aim to explore deep meanings, relationships, or nuances between our qualitative data and quantitative data; therefore, qualitative analyses were not used.

3 Results

Using crosstabulation, we examined personal characteristics of farmers who did adopt cover crops (Table 2) with 46.8% of respondents having adopted cover crops ($f = 36$) and 53.2% having not adopted ($f = 41$). Of the respondents who did adopt cover crops, 58.3% ($n = 21$) were 51 to 70 years, 55.6% ($n = 20$) were females, and 94.4% ($n = 34$) were White. Over half of farmers who did adopt cover crops also had either a graduate (22.2%; $n = 8$) or bachelor's (36.1%; $n = 13$) degree. Lastly, 36.1% of farmers who did adopt cover crops ($n = 13$) reported they attained 81 to 100% of their household income from agricultural production. We examined Spearman rho correlation coefficients for each demographic variable, aside from gender (categorical variable), which was examined using a chi-square test. We found a weak negative correlation where educational reasons for cover crop adoption grew as farmers obtained smaller amounts of income from agriculture [$\rho(70) = -0.261$, $p < 0.05$]. All other correlations (Spearman and chi-squared) were not significant.

Using crosstabulation, we also examined total acres farmed, percent of acres irrigated, crop type, and number of years in agriculture for farmers who did adopt or did not adopt cover crops (Table 3). Most farmers who adopted cover crops (52.8%; $n = 19$) farmed 0–1,000 acres of land. Of adopting farmers who farmed any number of acres, the largest majority (38.9%; $n = 14$) did not irrigate land, followed by 22.2% ($n = 8$) who irrigated between 81 to 100% of their farmed land. Additionally, most adopting farmers (61.8%; $n = 47$) farmed annual crops, followed by small grains (22.4%; $n = 17$)

and perennial forage (14.5%; $n = 11$) with remaining farmers having only livestock (1.3%; $n = 1$). Last, half of adopting farmers spent three or less years in agriculture (50%; $n = 18$).

We calculated a between-subjects single factorial MANOVA, comparing perceived economic reasons, perceived educational reasons, and perceived personal beliefs for farmers' cover crop adoption (Table 4). For farmers who did adopt cover crops, we found no significant effect [Wilk's (3, 74) = 0.969, $p = 0.512$]. Cover crop adoption did not influence perceived economic reasons, educational reasons, and personal beliefs.

We also calculated a between-subjects single factorial MANOVA, comparing farm characteristic barriers, personal belief barriers, economic barriers, and educational barriers for farmers' cover crop adoption (Table 5). For cover crop adoption, we found a significant effect [Wilk's (4, 72) = 0.849, $p = 0.018$]. Economic barriers were perceived as a smaller hurdle for farmers who did adopt cover crops ($M = 2.869$, $SD = 0.902$) when compared to farmers who did not adopt cover crops ($M = 2.272$, $SD = 0.708$). Farm characteristics were also perceived as less of a barrier for farmers who did adopt cover crops ($M = 3.347$, $SD = 0.984$) when compared to farmers who did not adopt cover crops ($M = 2.835$, $SD = 0.908$).

Last, *post hoc* tests were not feasible because MANOVAs with two-level independent variables do not permit such analyses (Armstrong, 2017; Scheiner, 2020). Therefore, we compared 95% confidence intervals of barrier measure item means to assess significance for those who did and did not adopt cover crops. Figure 2 indicated that, among the economic barriers measured, the input cost and equipment cost items were significant barriers to cover crop adoption.

4 Discussion

Drawing on social cognitive theory (SCT) and the theory of normative social behavior (TNSB), the study's main objective was to examine beliefs and barriers associated with farmers' cover crop adoption in the Southern Great Plains region of the U.S. Amongst our most notable findings were those farmers who adopted cover crops viewed economic barriers and farm characteristics as less of a barrier to adoption than those who did not adopt. This association may be due to cover crop adoption's added costs. Farmers who could afford the cost and had the farm resources necessary to adopt cover crops were more likely to adopt.

Highlighting age, farmers in our study were more likely to adopt cover crops than others if they were between ages 51 and 70, aligning with Knowler and Bradshaw's (2007) and Prokopy et al.'s (2019)

findings. This could be because farmers at this age may be more knowledgeable about and more comfortable with their current practices, believing benefits of learning and implementing new practices outweigh implementation costs. Furthermore, farmers who have worked in agriculture longer have also accumulated larger networks of peers, which may influence their adoption behaviors. According to Bandura's (1997) SCT, influence from peers can lead to greater behavioral change. It is possible that this farmer age group has a peer network that shares rich agricultural knowledge with them, shaping the behaviors of farmers in this age range. This age group's connection to knowledgeable peer networks is strengthened by TNSB's group identity cognitive mechanism, which moderates and mediates the relationship between these farmers' descriptive norms (i.e., regularly enacting farming practices that align with their knowledgeable peers) and behaviors (i.e., behaviors based on these peers' influences) (Rimal, 2008; Rimal and Real, 2005; Carcioppolo et al., 2017).

Farmers in our study who were 71 years old and older were also less likely to adopt BMPs, which was congruent with Arbuckle and Roesch-McNally's (2015) study. It is possible that farmers in this age group may perceive they do not have the capability or drive (e.g., physically, financially, planning to retire, etc.) to learn and invest in new practices. Additionally, pertaining to SCT's peer influence and TNSB's group identity concepts, there might be something unique about this group's identity or their peer group driving this pattern. For example, as an older group, this age cohort may collectively convince each other (peer influence) that they already use effective management practices without adopting Arbuckle and Roesch-McNally's (2015) BMPs, based on their years of farming experience and established expertise (group identity).

Our results also showed that those who did adopt cover crops had more years of formal education than non-adopters, which is congruent with previous research (Asfaw and Neka, 2017; Mango et al., 2017; Denny et al., 2019). This is possibly because individuals with more extensive, formal education have greater access to academic literature, resources, and information on BMPs. Formally educated farmers may have learned where and how to access information, been involved in BMP conversations, learned how to interact with scientific jargon, and been more open to progressive agricultural practices. This finding aligns with SCT because components like self-efficacy and behavioral capacity are driven by an individual's level of knowledge about a behavior they are attempting to enact (i.e., cover crop adoption) (Bandura, 1997). Lack of knowledge or formal education could, therefore, contribute to lower self-efficacy and perceived behavioral capacity. Educated farmers may also have networks, connections, or familiarity with professional resources, which would also instill

TABLE 4 The multivariate analyses of variance *F* ratios for cover crop adoption (Yes) effects for perceived educational reasons, perceived personal beliefs, and perceived economic reasons measures.

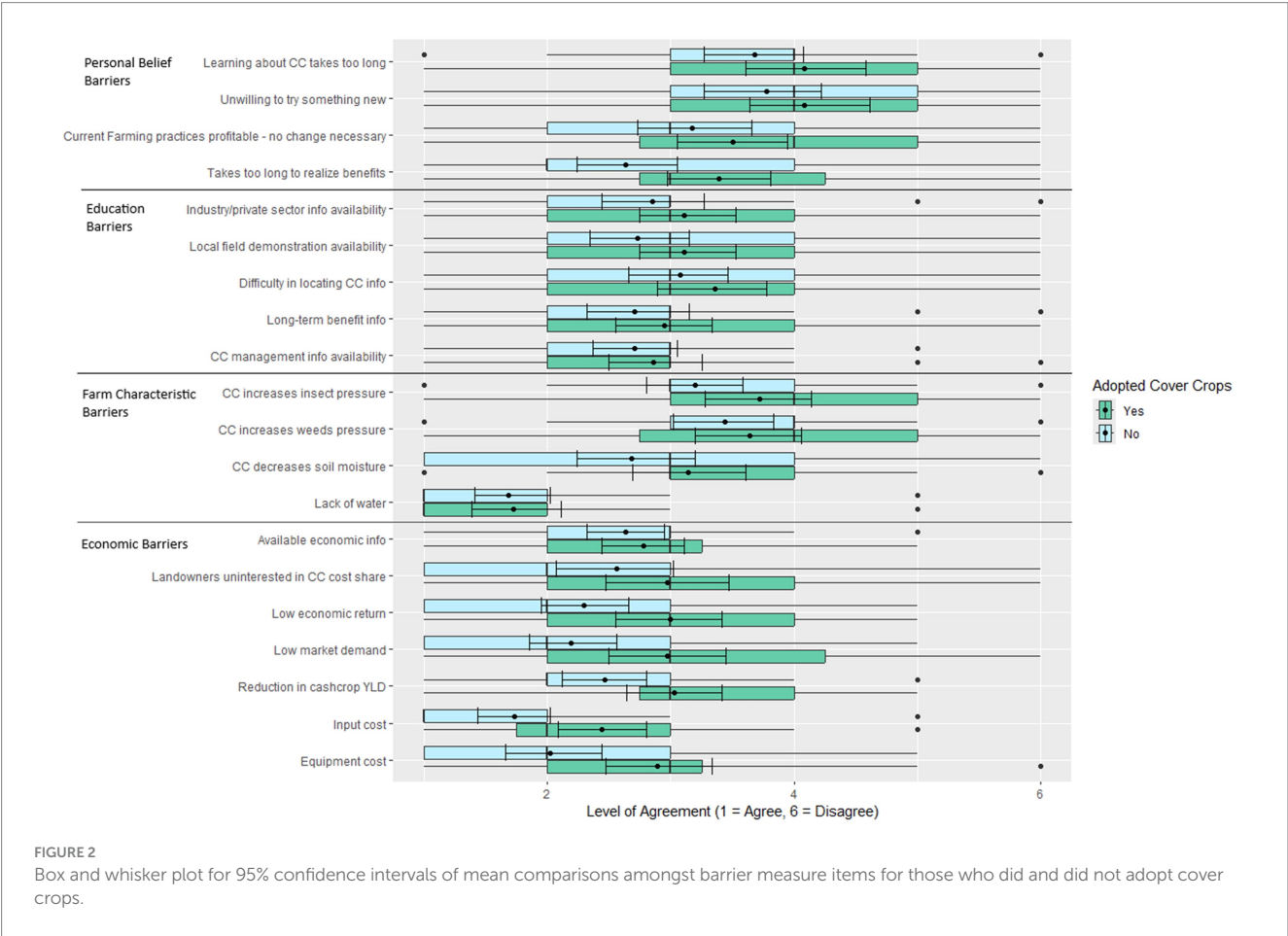
Source	Univariate											
	Multivariate			Perceived educational reasons			Perceived personal beliefs			Perceived economic reasons		
	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2
Cover crop adoption (yes)	24.90	0.512	0.96	1.72	0.193	0.02	1.09	0.30	0.01	0.15	0.70	0.002

The multivariate *F* ratios were generated from Wilk's statistic. Multivariate *df* = 3, 74. Univariate *df* = 1, 76. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

TABLE 5 The multivariate analyses of variance *F* ratios for cover crop adoption (No) effects for farm characteristic barrier, personal belief barrier, economic barrier, and educational barrier measures.

Source	Univariate														
	Multivariate			Farm characteristic barriers			Personal belief barriers			Economic barriers			Educational barriers		
	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2
Cover crop adoption (no)	3.21	0.018*	0.95	56.34	0.02*	0.07	2.93	0.09	0.04	10.57	0.002**	0.12	1.08	0.30	0.01

The multivariate *F* ratios were generated from Wilk's statistic. Multivariate *df* = 4, 73. Univariate *df* = 1, 76. **p* < 0.05. ***p* < 0.01. ****p* < 0.001.



confidence in pursuing the sometimes long and complex process of implementing BMPs.

In our study, gender was not significantly correlated with economic reasons for cover crop adoption. This contradicts prior research showing that women were more likely than men to adopt environmentally conscious behaviors (Wang et al., 2021a; Atkinson, 2014; Logsdon-Conradsen, 2011). This is important because women play a vital role in environmental conservation advocacy and were just more than half of our participants (57.14%; *n* = 44). TNSB states society's social normative beliefs have developed through social normative behavioral perceptions (Lapinski and Rimal, 2005). This aligns with research, showing men have been encouraged to provide for the family economically by traditional socialization practices, referred to as playing the "breadwinner" role (Hunter et al., 2004).

Thus, male farmers may be less likely to adopt costly practices without a clear economic benefit. Social expectations influence women's involvement in pro-environmental behaviors (Druschke and Secchi, 2014), and men, when compared to women, are less likely to engage in pro-environmental behaviors (Desrochers and Zelenski, 2023). Thus, greater pro-environmental intentions among female farmers may be more important in shaping female farmers' behaviors than their perceptions of the potential economic barriers.

There was also no significant effect of farmers' perceived economic reasons, educational reasons, and personal beliefs on cover crop adoption. This was an interesting finding for several reasons. First, previous work has suggested beliefs about the economic value of cover crops are associated with adoption behavior (Bowman et al., 2016; Carlisle, 2016; Roesch-McNally

et al., 2017; Dessart et al., 2019; Campbell et al., 2021; Duke et al., 2022; Kissel et al., 2023). Second, education and the percentage of income earned (as demographic items) were significantly associated with adoption. Therefore, there appears to be an important relationship here, even if farmers do not perceive beliefs about these factors to be important. It is also possible this is related to cognitive lock-in in agricultural communities (Wald et al., 2025), where most participants believe that economic factors are very important to others, but in reality, farmers could be equally concerned about land stewardship, family legacy, or a desire for healthy soil or water.

Moreover, while economic adoption benefits were not an influential reason for cover crop adoption, economic adoption barriers were seen as a significant reason for why farmers did not adopt cover crops. This could be because some farmers in our study who did not adopt cover crops (14.6%) received all or most of their household income (81 to 100%) from agriculture. Relating to SCT's self-efficacy, perceived economic barriers would be a vital reason for not adopting cover crops due to additional input costs hindering farmers' belief in their ability to adopt cover crops (Bandura, 1997). It is possible this finding is related to a lack of knowledge about incentive programs. As other research suggests, many farmers are not aware of incentive programs available to offset the adoption costs for cover crop practices or believe incentive programs do not cover the full cost of cover cropping (Roesch-McNally et al., 2017; Duke et al., 2022; Kissel et al., 2023). Other researchers have found incentive programs do not have adequate resources (i.e., staff) to efficiently support farmers in finding programs that align with their practices and goals, let alone getting farmers enrolled in programs (Wald et al., 2025), which could be a factor in this context as well.

It should also be noted that most respondents in our study (75%) reported having some type of supplemental income. Due to the high input costs, inflation, low profit margins, and unstable market prices needed to produce agricultural commodities, some farmers seek to supplement their income. This can help farmers maintain a stable income or provide them with critical health and retirement benefits through alternative employment. Supplemental income requires time spent away from agricultural production, which has, in other studies, contributed to reduced time for the implementation of BMPs (Asfaw and Neka, 2017). Thus, it is possible that the diversified income sources reported by our respondents reduced time on the farm, limiting their ability to adopt BMPs like cover cropping. Perhaps, if BMPs were as profitable as other supplemental incomes, farmers could adopt them instead of pursuing supplemental income.

Farm characteristics also provide insight into reasons for adoption. The amount of farmland operated by each farmer (0–1,000 acres, 68.8%, $n = 53$; 1,001–3,000 acres, 16.9%, $n = 13$; 3,001+ acres, 14.3%, $n = 11$) affects cover crop adoption due to the time and resources required to practice cover cropping, which again touches on a farmer's belief in their inability to adopt cover crops (i.e., SCT's self-efficacy) (Bandura, 1997). Those with the least number of acres farmed were likely to have time to manage additional crops when compared to larger farms that require more personnel, labor, time, and money for management, inputs, and resources. Thus, farmers move below the break-even point, creating a situation where farmers cannot remain profitable if they operate 3,001 acres or more. For these same reasons, farming several thousand acres can become a barrier to adoption.

Furthermore, based on acres farmed, farmers in our study who did not irrigate at all and those who irrigated 81 to 100% of acres farmed were both the largest groups of farmers who adopted cover crops. This could be because farmers who do not irrigate may already be employing BMPs (i.e., water conservation) by not irrigating and using cover crops to enhance their conservation practices. It is also possible that those who irrigate most or all of their acreage are looking for conservation practices that do not eliminate irrigation but extend water resources. Adoption reasons could also be tied to SCT's reinforcement component, where conservation practices are being adopted based on economic incentives (Bandura, 1997). These differences in irrigation levels are likely influenced by water capacity, infiltration, reduced evaporation, and preserved soil moisture (Blanco-Canqui, 2018). Specifically, farmland that is not irrigated (0%) is more susceptible to degradation due to a lack of soil structure (Blanco-Canqui, 2018), increasing the need for cover crops that provide land cover and soil structure. This finding may also be tied to farmers' perceived concerns about the potential for cover crops to reduce soil moisture (Wallander et al., 2021).

A majority of farmers who adopted cover crops also produced annual crops (61.8%; $n = 47$). Annual crop farmers may have been more likely to adopt cover crops for two reasons. First, cover crop seed mixes designed to be compatible with annual crops could be more readily available and have more research supporting their use, compared to other types of crops. Second, rotating between annual cash crops and cover crops may be more convenient because annual crops are planted and harvested each year, leaving bare farmland available for planting cover crops. In contrast, there may be anticipated interference between perennial and cover crops because perennial crops have different growth cycles.

Lastly, in terms of barriers, personal belief barriers and educational barriers were not associated with cover crop adoption. It is possible education was tied to the identity of this group of farmers because most of the farmers who responded had completed high school and college.

4.1 Limitations

As with any research, our study has limitations that should be addressed in future research. First, for our study, farmers' perceived economic reasons, educational reasons, and personal beliefs had no significant effect on cover crop adoption. However, prior research found cover crop adoption beneficial for other reasons and beliefs not addressed in our study, like feeding livestock (Planisich et al., 2021), companion planting, crop rotation (Verret et al., 2017), regenerative agriculture, nutrient cycling (Runck et al., 2020), increasing biodiversity (Adetunji et al., 2020), pest control, and disease management (Kumar et al., 2020). Therefore, future studies should examine other beliefs that may be associated with adoption behaviors. Our questions also did not use "land value and productivity" or "additional revenue" terminology, which other scholars found important (Adeux et al., 2021; Carlisle, 2016). Future scholarship could compare these items more directly or allow farmers to rank these beliefs in terms of priority.

Additionally, farmers in our study who irrigated 81–100% of acres farmed and farmers who did not irrigate any acres were both the largest farmer groups to adopt cover crops. This could be because

farmers who do not irrigate may already be employing BMPs by not irrigating and using cover crops to enhance their conservation practices. Moreover, those who irrigate most or all of their acreage may be seeking conservation practices that do not eliminate irrigation but extend water resources. Additional research on the location of these farmers and reasons for these different types of farmers would shed light on these findings. We also cannot draw more conclusions from these reasons because we did not measure these items. Future research on this topic could combine social and environmental determinants to create a more robust model of cover crop adoption.

Farmers' beliefs and behaviors were self-reported, which can be biased or inaccurate, based on respondents' own beliefs. Collecting responses through a survey also required respondents to answer using *a priori* scaled questions, not allowing respondents to provide detailed information about adoption behaviors, cover crop adoption reasoning, or land stewardship objectives. Implementing a mixed methods approach in future studies (i.e., by including interviews) could improve these results by examining the reasoning for their responses.

Additionally, our study's Cronbach's Alpha for Economic Reasons was .65. Although this score is still adequate and acceptable by some scholars (Taber, 2018), especially for a set of items in a new scale, this lower value (below .70) could be due to this study's smaller usable sample. Therefore, future research should survey a larger portion of the Southern Great Plains to address this.

Lastly, annual crops were reported in the crop type category of our results, but farmers may have different adoption preferences for different annual crops (e.g., soybeans, winter wheat, corn, etc.). Due to the limited number of usable data from farmer respondents preferring mailed surveys over digital ones, we could not run data analyses that required dividing annual crops into specific annual crop types because groups would have too few responses per grouping for analysis. Therefore, future research should specifically examine different crop types within the context of cover crop adoption preferences and perceptions. Our study also did not examine how adoption perceptions vary across different cover crop species. Different species should be examined in future cover crop adoption research to see what differences in adoption perceptions arise.

4.2 Recommendations

In terms of practical implications, our study identified possible reasons for low cover crop adoption rates in this region that can inform soil and water conservation professionals, government or industry-funded cover crop programs, and other agricultural or natural resource organizations seeking to encourage cover crop adoption in semi-arid regions. Our findings provide insight into the demographic make-up of farmers in the Southern Great Plains of Texas and Oklahoma who choose to adopt cover crops. These data can help identify strategies to encourage greater adoption among farmers with similar habits. Additionally, this work provides insights that could be beneficial to industry professionals who wish to develop cover crop seed mixes and application information for annual crop farmers. This can help extension agents, government and industry representatives, and soil and water conservation professionals target crop farmers who may be interested in cover crops but are hesitant to adopt because current seed mixes do not include cover crop varieties. Messages

could also be developed about mixes and application information through farm visits, field days, and other platforms preferred by crop farmers.

Because input costs and equipment costs are significant barriers to cover crop adoption, government subsidies and incentive programs should consider these costs when developing and revising current and new programs. Organizations that manage incentive programs could consider partnering with commodity and farmer organizations that have access to the target audience as well. Current partners can help disseminate cover crop information and reasons for adoption while considering cost barriers of specific populations to allow additional partnerships to be obtained (e.g., agricultural economists, agricultural loan corporations, etc.). Such professionals can consider developing input and equipment financial worksheet-based materials to accompany information on incentive programs to guide farmers in making informed decisions.

Reasons for and barriers to cover crop adoption based on place and commodity should also be investigated to provide practically applicable information to specific agricultural populations. Investigating the impacts of education specific to cover cropping and other BMPs should be considered to provide recommendations for connecting communication, credibility, and education strategies that influence adoption behaviors. Additionally, some decisions about adoption are out of farmers' control. Thus, organizations such as the USDA and NRCS can consider conducting program evaluations to determine if there are internal barriers (e.g., understaffing) hindering farmer enrollment in incentive programs. Furthermore, promoted BMP incentive programs are sometimes not aligned with agricultural policies related to specific BMPs, so organizations need to be more intentional about aligning incentive programs with agricultural policy criteria.

Behavior change is also a complex process, and behaviors can be affected by stakeholder interventions (Hollister and Anema, 2004). Our work sheds light on the drivers of behaviors that could provide insight into how individual farmers' beliefs influence farmer group norms, which in turn, may shape farmer behaviors across groups. Researchers should continue to examine how different farmer demographic groups respond to cover crop adoption practices and how much farmers' financial realities, demographic make-up, and economic barriers contribute to their adoption of cover crops. Our work sought to expand the applicability of social cognitive theories like STC and TNSB to the context of agricultural and cover crop research.

5 Conclusion

Ultimately, our study provides valuable insights into water conservation practice adoption in the Southern Great Plains of Texas and Oklahoma. Further, the current study uncovers crop adoption usefulness for farmers, being a modern tool for conservation practice implementation. Information on personal and farm characteristics, as well as reasons and barriers to adoption, can also give farmers, policymakers, industry professionals, and communities a sense of what populations in Texas and Oklahoma are doing to conserve water in agricultural practices. Our study expands the application of the theory of social normative development to a new context and provides insights about practical ways to help farmers adopt cover crops.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repository and accession number(s) can be found at: <https://doi.org/10.6084/m9.figshare.29190818>.

Ethics statement

The studies involving humans were approved by Texas A&M Human Research Protection Program. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

PJ: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. EF: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. HL: Project administration, Supervision, Writing – review & editing. PL: Formal analysis, Investigation, Writing – review & editing. DW: Project administration, Supervision, Writing – review & editing. TB: Funding acquisition, Investigation, Resources, Supervision, Writing – review & editing. SdV: Funding acquisition, Resources, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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