Exploring Wheat Farmers' Soil Health Management Practices, Adoption Characteristics, and Information Preferences

Healthy soil is critical to feeding and sustaining human and animal populations and ensuring the land is productive for years to come (Kopittke et al., 2023) because the strength of planet health hinging on the multifunctioning capacity of healthy soil. Kopittke et al. (2023) described a shift in defining healthy soil as productive and strong for growing food to defining healthy soil from a perspective of its role in the ecosystem and sustaining healthy humans and a healthy planet. Kopittke et al. (2023) defined soil health as "the ability of the soil to produce biomass, regulate the C pool, provide habitat for biodiversity, cycle nutrients, and cycle water" (p. 217). Other scholars, however, have defined healthy soil as abundant with organic matter, maintaining nutrients, holding moisture, supporting microorganism activity (Jones et al., 2022), maintaining healthy microbial activity (Larkin, 2015), and providing ideal conditions for soil vitality (Lal, 2016). Because of soil's role in maintaining a healthy ecosystem and contributing to a healthy planet, soil health management should be considered an overarching priority for agricultural systems management.

Yet, farmers are hesitant to adopt soil conservation and soil health management practices (Wuellner et al., 2018) and help protect soil structure, soil health, and plant ecosystems (Carlisle, 2016; Turmel et al., 2015). There are two important soil health management practices can help preserve the land: reducing tillage and planting cover crops. Strip-tillage, a type of reduced tillage that leaves at least 30% of biomass (residue) on the soil's surface, is a conservation tillage method (Wade et al., 2015). Strip tillage is less invasive than conventional tillage and greatly improves wheat yields because it results in enhanced rate of leaf development and photosynthesis (Saldukaitė et al., 2022). No-tillage protects soil because it increases soil organic matter, enhances soil structure, and decreases soil erosion by leaving the ground undisturbed (Deng et al., 2022; Feng, 2018). Soil moisture retention is improved in no-till systems, making wheat production more feasible (Yang et al., 2021). In contrast, conventional tillage disturbs subsoils and exposes soils to sun and moisture evaporating conditions (de Medeiros Barbosa, 2015), and conventional tillage can negatively impact soil organic matter resulting in decreased fertility and nutrients (Hutchinson, 2012). Conventional tillage combined with wind, lack of water, decay of soil organic matter, and breakdown of soil structure have contributed to soil erosion (Lal, 2015).

The benefits of cover crops are many, including reducing erosion and water loss, curbing pest activity, replenishing soil nutrients (Warren et al., 2017), reducing nutrient application, improving soil health, and increasing farm yields (Dunn et al., 2016). Yet, research suggests that cover cropping benefits are not equal across region or across individual farms as Dunn et al. (2016) argued that the benefits are only as beneficial as the farm and its unique characteristics will allow. In Texas, a specific region within our study, cover crop management is based on careful timing of rain, planting, and invasive weed growth (Mowrer, 2020) while cover cropping in Oklahoma is a relatively new practice (Warren et al., 2017). As such, Warren et al. (2017) recommended planting a test plot of cover crops to determine their effect before using them on the entire operation. Similarly, in Louisiana, a South Central region state, Sanchez et al. (2019) suggested farmers looking to increase essential soil nutrients (e.g., nitrogen, potassium) consider long-term cover crop implementation.

Educating farmers about the importance of managing soil health and implementing soil health practices, like reduced tillage and cover crops, has the potential to improve soil organic carbon and provide the ideal soil conditions to prevent water seepage, improve aggregate stability, and maintain hardiness in extreme or inconsistent climates (Maharjan et al., 2020). Dunn et al. (2016) described landowners as being a critical piece to the communication puzzle as their influence could persuade land managers to adopt conservation practices. Lavoie et al. (2021), in a Pacific Northwest study, found more specific information on cover crops is needed for cover crop adoption to be successful. Specifically, Lavoie et al. (2021) argued more region-specific, field-level information targeted at the individual farmer or farmer groups is needed. Similarly, in a Midwestern study, Plastina et al. (2020) found that more information is needed to quantify the “short-term costs and long-term benefits” (p. 46). Data are available about the benefits of cover cropping, but specific data quantifying the benefits is still lacking (Plastina et al., 2020). Accordingly, increasing farmers' scientific understanding of soil health management practices is a critical first step to implementation as perceptions, behaviors, and attitudes often influence intent to adopt (Abbot et al., 2002; Dunn et al., 2016; Morrison et al., 2017; Prokopy, 2019).

The literature highlights the importance of farmers having scientific and local knowledge regarding farming (Ingram, 2008). Scientific knowledge is described as explicit or technical knowledge that can be organized systematically, documented, stored, and shared (Norgaard, 1984). McCorkle (1989) described tactile knowledge as local knowledge that has to do with theories, beliefs, or practices without input from formal scientific methods. Likewise, sustainable agriculture requires the adoption of technologies that require high levels of management skills specifically regarding observation and monitoring (Park et al., 1997; Roling & Jiggins, 1994). Successful implementation of sustainable practices depends on farmers’ understanding of the underpinning scientific principles and physical processes (Pretty, 1995; Vanclay & Lawrence, 1994) as well as “the heterogeneity of soils, farming systems and management options, coupled with the changing agricultural landscape towards company-managed farms, absentee landowners[,] and increased reliance on contractors” (Rust et al., 2020, p. 11). Therefore, farmers need both technical knowledge of soil management practices and tactile knowledge to manage soil sustainably (Ingram, 2008).

Scott and McGuire (2017) noted that using evidence-based communication and education strategies to disseminate scientific research findings about technology innovations is one way to increase scientific understanding and, thereby, encourage adoption. In 2003, Andrews et al. wrote farmers are rarely consulted by researchers regarding their knowledge of soil, yet more recent research (Pauli et al., 2016) has indicated understanding and respecting how farmers view soil can help improve agricultural extension programs and soil management initiatives. Although farmers are typically well-informed about managing their agricultural operations, their scientific knowledge and understanding regarding more complex soil management practices is limited (Ingram, 2008). Therefore, prior to initiating effective communication and education strategies, farmers, researchers, and Extension program specialists should seek to understand farmers’ beliefs, behaviors, and perceptions related to the innovation (soil health management practices for our study), their information needs, and their preferred information sources (Dewald et al., 2019; Morrison et al., 2017).

Closing the knowledge gap in agricultural production practices is an essential job of Extension, according to a 2019 Dewald et al. study. Yet, Rust et al. (2022) noted farmers are skeptical of the traditional experts and might question their intentions prior to adopting information they deliver. Instead, farmers in the Rust et al. (2022) study turned to influencers in the community (change agents or opinions as described by Rogers in 2003) as an expert source. Extension professionals spend much of their time creating and curating educational programming to meet farmers’ needs (Beattie et al., 2022; Kopiyawattage et al., 2018), but farmers like those in the Rust et al. (2022) study are starting to question a conflict of interest. To develop targeted programming designed with farmers’ interest in mind, Extension professionals must, first, identify farmers’ current attitudes and knowledge about an innovation and their preferred means of receiving information, which can be done through the intentional building of relationships with the targeted farmer group (Rust et al., 2022).

Taylor and Bhasme (2018) discovered relationships are often a precursor to effective communications, and establishing those relationships takes time and requires intentional interaction with local agricultural leaders, a group Rogers (2003) labels as opinion leaders. This knowledgeable group is a critical piece to innovation dissemination and is often willing to experiment with an innovation before their peers (Rogers, 2003; Taylor & Bhasme, 2018) because they know how to generalize scientific information to their operations (Dunn et al., 2016). Thus, by leveraging the target group of local agricultural opinion leaders, researchers and Extension professionals can accelerate the adoption of an innovation (Arbuckle & Ferrell, 2012; Dunn et al., 2016; Lavoie et al., 2021).

To further accelerate adoption of soil health management practices, Extension professionals need to familiarize themselves with the information needs and preferred information sources of farmers (Rust et al., 2020). Research indicates farmers who plant maize, a cereal grain, in Ghana trust Extension professionals the most for agricultural information (Taku-Forchu et al., 2023) with grain farmers primarily receiving agricultural information from mass media channels like radio, television, and newspapers, and through interpersonal communication such as Extension professionals, fellow farmers, and friends/neighbors (Hall & Rhoades, 2010; Taku-Forchu et al., 2023). Additionally, Hall and Rhoades (2010) found, when farmers consider adopting farming practices, they typically refer to farming publications. Farmers in Hungary and the UK found farmers placed more trust in the local farm press than they did in their local farm advisors, yet they were still skeptical of the content in the farm press (Rust et al., 2022).

In Prokopy et al.'s 2019 study on 30 years of cover crop adoption, social networks were an important information source because farmers who participate in such networks are more likely to adopt conservation practices than those who do not. These social networks (Prokopy et al., 2019; Ranjan et al., 2019) are an important method of communication and interaction as farmers across studies have noted field demonstrations and local meetings are preferred sources of communication because farmers can interact with Extension and industry professionals (Bruenig, 1991; Hall & Rhoades, 2010; Taku-Forchu, 2023). Farmers often trust their peers more than they trust other stakeholders (Ranjan et al., 2019; Rust et al., 2020; Rust et al., 2022). Yet, Dunn et al. (2016) concluded there may be differences in how producers receive information based on their rate of adoption—innovators and early adopters prefer online resources and late adopters prefer alternative channels. However, in addition to Extension events as a pathway for disseminating information about the benefits of cover crops, Ranjan et al. (2019) and Rust et al. (2022) noted farmer influencers and community leaders can help establish conservation social norms within a community. Lavoie et al. (2021) noted "future cover crop research should be conducted in close collaboration with producers to build their capacity, demonstrate site-specific compatibility[,] and provide the opportunity for peer-to-peer learning" (p. 392). Literature suggests, then, that cover cropping research and information dissemination should be conducted in the presence of peers if adoption rates are to improve.

Furthermore, in 2020, Lawson et al. found producers prefer face-to-face communication and email to share concerns, opinions, knowledge, and personal stories, and Gibson et al. (2020) found tailoring messages, outreach programs, and communication channels to region specifics and rurality is crucial because preferences vary significantly by region. Regarding agriculture and natural resource policy and regulations, Lawson et al. (2020) suggested Extension professionals train farmers and ranchers to act as opinion leaders and facilitate change among the agricultural industry because of their impact on local producer decisions. These insights underscore the pivotal role of Extension professionals in facilitating informed decision-making and in moving the adoption of sustainable agricultural practices forward.

Theoretical Framework

Rogers' (2003) diffusion of innovation theory guided the study described herein. Rogers' diffusion of innovation theory has long been a study used to understand farmers' motivations for adopting conservation practices (Ranjan et al., 2010), and it is pivotal to understanding behaviors that enable or inhibit the adoption of innovations (Simin & Jankovic, 2014). Rogers (2003) explained the change process through the lens of rural sociology and provided methods for assessing innovation adoption and determining influential elements (e.g., innovation, communication sources and mediums, time, and social system) for spreading information about a new idea (Sahin 2006; Wehmeyer et al., 2022). An innovation is an idea, practice, method, or object an individual or group considers new to them. Communication about innovations is achieved either through mass media or interpersonal communication sources (McGuire et al., 2022; Rogers, 2003; Sahin, 2006). An individual's social system consists of their community of practice, which most often includes change agents and opinion leaders who serve as critical players in the adoption process. These groups typically focus on common objectives defined by the groups' leaders and individual members (Rogers, 2003; Sahin, 2006). Rust et al. (2020) described social capital as being a factor in understanding adoption of soil management practices. Each component (e.g., innovation, communication sources and mediums, time, and social system) is essential to the innovation-decision process and has the power to influence the adoption decision. Extension professionals' involvement in each stage is key for supporting longitudinal adoption (Dewald et al., 2019; Rogers, 2003; Seevers & Graham, 2012).

The innovation-decision process has five stages—knowledge, persuasion, decision, implementation, and confirmation—individuals experience when determining the advantages and disadvantages of adopting an innovation and, ultimately, making the decision to adopt or reject (Rogers, 2003). First, individuals obtain *knowledge* about an innovation—they seek what the innovation is, how the innovation functions, and why they need the innovation. For example, field days would be the ideal setting for farmers to gain knowledge and information about agricultural innovations, and farmers want and need interaction and more information (Lavoie et al., 2021). Second, during the *persuasion* stage, individuals develop a desirable or undesirable attitude about an innovation. Often, in this stage, farmers seek a relative advantage (Rogers, 2003), especially an economical advantage (Lavoie et al., 2023; Reimer et al., 2012a, 2012b). Farmers suggested this barrier could be mitigated through integrating livestock into cropping, using alternative crops, or providing economic data to support region-specific implementation of cover cropping (Lavoie et al., 2023).

Third, in the *decision* stage, individuals decide to accept or reject the innovation in either the short term or long term. Trial is critical to this stage, and an individual's experience with the innovation in the trial period is a strong indicator of intention to adopt an innovation long term (Rogers, 2003; Sahin, 2006). Lavoie et al. (2021) found producers perceived cover cropping as low trialability because it is a complex practice that takes time and energy to test, yet local research was one-way farmers recommended this barrier could be overcome. Fourth, at the *implementation* stage, individuals have decided to fully implement the innovation. In this stage, an individual seeks to establish confidence in the innovation, which may require a change agent or opinion leader (Rogers, 2003; Sahin, 2006). Finally, *confirmation* occurs after an individual adopts an innovation. Here, individuals seek affirmation or support for their decision (Rogers, 2003; Sahin, 2006).

In addition to the five stages of adoption, Rogers (2003) defined five categories of adopters—innovators, early adopters, early majority, late majority, and laggards. *Innovators* are venturesome, are influential, can navigate challenges easily, and are knowledgeable about complex technical applications (Rogers, 2003). Their thirst for knowledge and understanding allows them to take adoption risks while others consider the pros and cons of adoption. *Early adopters* are characterized by their positivity within a social system and their ability to make discrete and astute innovative judgments as they seek to discover an innovation's effectiveness, but they lack leadership skills (Rogers, 2003). They adopt innovations prior to most individuals and, thus, influence their community or group because their decision to approve and/or adopt an innovation triggers their peers to adopt subsequently (Rogers, 2003).

Early majority adopters rarely hold a position of influence. They tend to make decisions after carefully considering an innovation's opportunities and costs and watching others try the technology (Rogers, 2003). *Late majority* adopters are agnostic individuals who adopt out of monetary necessity or peer insistence. Jemison et al. (2018) recognized providing opportunities for innovative leaders to engage with those less innovative in the community is critical to widespread adoption of innovations. *Laggards* are last to or refuse to adopt an innovation. They are skeptical traditionalists who use their past to validate their adoption suspicions and typically hold independent views in a social system (Rogers, 2003).

Agricultural regions of Texas, Oklahoma, and Louisiana with wheat farming served as the geographic focus of our study because the three states were a part of a larger funded project. Farmers in the South Central United States, including Texas, Oklahoma, and Louisiana, need region-specific data on how soil health management practices can improve soil health, which aligns with Hamilton et al.'s (2017) and Lavoie et al.'s (2021) claim that region-specific research on conservation practices is lacking. Because of the need for region-specific data, the overarching funded project established region-specific soil health data to help farmers make management decisions. Our study was a foundational study to understand wheat farmers in three states of the South Central and their awareness of healthy soil, current soil health management practices, adoption characteristics, and preferred information sources, and helped guide the project and the dissemination of information related to the project (Ranjan et al., 2019). Two communications-focused research studies followed the current study as we sought to understand wheat farmers in the region. The overarching project sought to benefit all South-Central United States wheat farmers by providing them the knowledge to make decisions about implementing soil health management practices, which is critical for soil scientists when making reliable recommendations to farmers and important to improving the trialability of cover cropping (Lavoie et al., 2021; Ranjan et al., 2019). Our study provides a path for soil scientists to understand wheat farmers in the region.

Purpose and Research Questions

The purpose of our qualitative study was to explore the soil health management practices, adoption characteristics, and preferred information sources of wheat farmers in Texas, Oklahoma, and Louisiana.

RQ1: How do wheat farmers in Texas, Oklahoma, and Louisiana describe healthy soil?
RQ2: How do wheat farmers in Texas, Oklahoma, and Louisiana manage soil health?
RQ3: Why do wheat farmers in Texas, Oklahoma, and Louisiana manage soil health?
RQ4: What drives Texas, Oklahoma, and Louisiana wheat farmers' interest in managing soil health?
RQ5: Why do wheat farmers in Texas, Oklahoma, and Louisiana choose to adopt or reject soil health management practices?
RQ6: What information sources and communications mediums do wheat farmers in Texas, Oklahoma, and Louisiana prefer when receiving information about soil health management practices?

Context of Study

Texas is a unique state with its varied weather patterns, more than 1,200 soil orders, many top-ranking agricultural commodities, and 248,416 farms and ranches occupying over 127 million acres (Texas Department of Agriculture, 2017). Texas has five wheat-growing regions—*Texas High Plains, Texas Rolling Plains, Texas Blackland Prairie, West Texas*, and *South Texas* (NASS, 2019)—that differ in soil order, which dictates how and to what extent each soil health management practice can be implemented. Wheat is an important contributor to the agricultural economy of Oklahoma with farmers spread across nine wheat growing regions. As in Texas, wheat is often used for livestock forage and grain. In 2019, wheat area sown in Oklahoma was 4.2 million acres, 2.75 million of which were harvested for grain. Total production was 110 million bushels (NASS Oklahoma Field Office, 2021). Agricultural production in Louisiana is diverse, generating $3.2 billion in 2020 (University of Arkansas Research and Extension, 2020). Louisiana wheat production totalled $3 million in 2018 with the highest grossing farms operating in seven of the 64 Louisiana parishes, two of which are in the *Central* agricultural district of the state. Wheat production yielded 517,381 bushels from 8,338 harvested acres belonging to the state's 39 wheat farmers (LSU Ag Center, 2018).

Methods

The qualitative study described herein was supported by the U.S. Department of Agriculture's Natural Resources Conservation Service. The data presented here are part of a large study, so similar methods may be described elsewhere.

Study Design

We conducted qualitative interviews to explore soil health management practices, adoption characteristics, and preferred information sources of Texas, Oklahoma, and Louisiana wheat farmers. Qualitative studies "can help identify themes that act as building blocks to generate testable hypothesis about farmers' conservation behavior reinforcements" (Ranjan et al, 2019, p. 1188). We used Roger's diffusion of innovations theory (2003) as the theoretical framework guiding interview question development. We then conducted data analysis using an inductive reasoning approach (Creswell & Poth, 2016) guided by open and axial coding to identify emergent themes across the data. In our discussion, we review the findings through recent conservation practice adoption literature. Ranjan et al. (2019) recommended qualitative studies to "explore farmers' motivations for, and barriers to, persisting with adoption" (p. 1188) and such studies be conducted that report findings in explicit themes. In addition, Hamilton et al. (2017) and Lavoie et al. (2021) call for more region-specific data on conservation practices because such research is lacking. We meet these calls with our qualitative study of South-Central United States wheat farmers.

Population and Sample

At the time of the study, Texas had approximately 2,000 wheat farmers, Oklahoma 1,500, and Louisiana 39. To ensure equal representation across states, we sought to align our sample numbers with the total number of wheat farmers in each state. Equal representation was critical as each state has diverse soil makeups and climates, which provide a unique farmer experience based solely on the state in which they produce wheat. Thus, aligning with Patton (2002), we identified 32 wheat farmers to represent our sample: 18 Texas farmers, eight Oklahoma farmers, and six Louisiana farmers. We combined the *Cross Timber, Blackland* and *Post Oak Savannah* ecoregions to represent the *Blackland Prairie* wheat region due to the low number of planted wheat acres in these ecoregions and did not interview farmers in *West Texas* because wheat trial research was not being conducted in that region at the time of the study. Oklahoma farmers farmed wheat in the *Oklahoma Panhandle, North Central Oklahoma,* and *Central Oklahoma* regions. Farmers had a generally high level of interest in managing soil health with 28 indicating a high interest in managing soil health and four indicating a neutral interest (based on question six of the interview protocol, described below). Farmers' land ownership and use characteristics are presented in Table 1.

Table 1
Farmers' Agricultural Land Ownership and Use (N = 32)

Soil Region by State	No. of Farmers	Wheat Acres	Acres Owned	Acres Leased	Tillage Methods	Management Decisions Influenced by Landowner
Texas						
High Plains	4	21,700	9,600	12,100	NT, ST, C	n = 1, 25%
Rolling Plains	7	31,288	7,610	23,678	NT, ST, C	n = 4, 67%
Blackland Prairie	4	10,039	2,440	7,590	NT, C	n = 3, 67%
South Texas	3	40,810	12,725	28,085	NT, ST, C	n = 1, 30%
Oklahoma						
Panhandle	1	3,785	3,110	675	ST	n = 3, 33%
North Central	6	500	500	0	NT, ST, C	n = 0, 0%
Central	1	42	42	0	NT	n = 0, 0%
Louisiana						
Central	6	5,544	2,892	2,652	NT, ST, C	n = 0, 0%

Note. NT = No-Till, ST = Strip-Till, C = Conventional.

We used purposive sampling (Merriam & Tisdell, 2016) in collaboration with county extension agents, university faculty, and crop consultants who connected us with farmers because many of them have long-standing relationships with farmers in their counties and areas. Our sample consisted of farmers who were influential in their respective agricultural communities and maintained relationships with local Extension personnel and crop production specialists. Recognizing the selection bias of the interview design, the findings reported here are not presumed to be representative of the broad population of wheat farmers. However, better understanding the perspectives, priorities, and farming practices of the farmers who participated in the study will generate important insights that can be used to communicate with wheat farmers and disseminate relevant information that could impact the adoption of soil health practices. Typically, wheat farmers operate as either the landowner or the tenant, which can greatly impact their ability to make on-farm decisions (Canales et al., 2018; Sawadgo et a., 2021) and should be considered when interpreting our findings.

Interview Protocol

We used Roger's diffusion of innovations theory (2003) to guide interview question development with the goal of exploring soil health management practices of wheat farmers in Texas, Oklahoma, and Louisiana. The interview protocol had 19 interview questions focused on farm demographics, farmers' definitions and examples of soil health, farmers' interest in and adoption of soil health practices, and farmers' sources of information about and perceived experts of soil health practices. We did not ask all farmers the 19 questions included in the interview protocol, but we did ask all farmers the first seven questions and the last three questions. We asked question eight (Does the landowner's opinion of soil health influence your management decision?) if the farmer indicated in question two that they leased more than 50% of the land they farmed. Farmers answers to questions one, two, three, and six are reported in the population and sample section of the methods because they were used to describe the population we studied. Questions nine through 16 were part of two separate tracks, and farmers were placed into one of the two tracks based on their answer to question six (On a scale of 1 (not) to 5 (highly), what is your level of interest in managing your soil health?) to determine a positive or negative/neutral line of questioning.

If farmers indicated no interest (one or two) or a neutral interest (three) in managing soil health, the subsequent interview questions aligned with the negative/neutral track of questioning with questions nine to 12 focused on considerations for and barriers to adopting soil health practices. If farmers indicated a high interest in managing soil health (four or five), the subsequent interview questions aligned with the positive track of questioning with questions 13 to 16 focused on motivations to and reasons for adopting soil health practices as well as indicators that practices are working. Before asking farmers the series of questions based on current level of interest, the interviewer provided a qualifying statement for soil health practices: "Soil health practices mean using reduced tillage, keeping the soil covered, and including a diverse cropping rotation potentially including cover crops." The statement was developed in collaboration with soil science researchers. The question helped us explore the adoption of soil health practices based on interest in managing soil health.

Finally, two questions on the interview protocol were close-ended questions that asked the participants about their preferred ways to receive information about soil health and their preferred sources of information. The questions were close-ended, and the answers were often single words or phrases. We report the answers below in narrative format.

Data Collection

We conducted the interviews both in person (e.g., on farm, at field days) and on the telephone between December 2019 and November 2021. We coded and analyzed the data in 2022. We planned to conduct all interviews in person but were unable to due to unforeseeable circumstances (e.g., COVID-19 pandemic, acts of Mother Nature). Interviews ranged in time between 30 and 60 minutes.

Data Analysis

Prior to data analysis, we separated the data into units, providing for rich interpretation of farmers' experiences with soil health management practices and communication about such practices (Patton, 2002). Each unit had a code that included the farmer, agricultural district or wheat growing region of operation, and statement number. To ensure conciseness in reporting of our findings, we report only the state and farmer no.

To analyze the data, we used an inductive reasoning approach, which allows for flexibility in identifying emerging patterns, themes, and concepts within the data (Creswell & Poth, 2016). We used open and axial coding to identify emergent themes and used constant-comparative methods to compare codes and themes while analyzing the data (Fraenkel et al., 2012). Two members of the author team analyzed the data concurrently and agreed on the themes and subthemes before making the final decision to categorize the unitized data accordingly. A member of the grant project team provided further review and debrief throughout data analysis.

A doctoral student and a faculty member coded the data with members of the larger grant team reviewing our data analysis. The doctoral student who coded the data was a secondary educator of agricultural mechanics and welding technologies and is a current pre-service agricultural teacher educator. She has personal experience in grazing cattle and sheep on forages and grains and believes soil health and the regenerative processes of soil are important. The faculty member who coded the data was an associate professor in agricultural science communications who has well-established, funded research program related to the study. She grew up in a top wheat production state in the Midwest, and her grandparents were influential, active wheat farmers in her home county. She was a Co-PI on the project that funded the study described herein.

We analyzed the data on three occasions to determine the data properly aligned with the chosen themes, and we reviewed the data a final time before reporting the findings. For those data that aligned with two themes, we categorized the unitized data according to the most prominent theme. During the analysis, we identified exemplar statements that represented the theme most appropriately. Using those exemplar statements, we crafted the findings narrative. Therefore, the findings are representative of the larger data set but are told through the lens of the most exemplar statements and interviews. We sought to make meaning of the findings through a discussion around farmer's perceptions of soil health practices, adoption characteristics, and preferred information sources. Data for research question six were analyzed using frequencies for each time a farmer mentioned preferred information sources and communication mediums.

We achieved credibility through prolonged engagement with the data (Ahmed, 2024) and data triangulation (Denzin 1978; Patton, 2002), and we achieved transferability by providing thick descriptions of the context of our study and participants (Ahmed, 2024; Lincoln & Guba, 1985). Furthermore, we achieved confirmability through peer debriefing among the researchers involved in the data analysis process (Creswell & Guetterman, 2021; Lincoln & Guba, 1985) and dependability through methodological documentation and audit trails (Ahmed, 2024; Lincoln & Guba, 1985).

Findings

How Do Wheat Farmers Describe Healthy Soil?

We found three emergent themes related to healthy soil descriptions: healthy soil is a living biome, healthy soil has texture and structure, and healthy soil is a costly responsibility.

Healthy Soil is a Living Biome

Many of the farmers we interviewed were knowledgeable individuals who understood soil health and expected soil to have high microbial activity and residue contents. “Healthy soil has earthworms, organic residue from cover crops, and a balanced soil PH” (TX07). One farmer described healthy land as having “good structure, deep topsoil, clay or sand that has the ability to hold water, and provision of nutrients for plants” (TX09)—its organic layers build deeper and deeper into [a healthy] soil structure” (OK02). It has “high organic matter and little sediment run off,” allowing for “water infiltration” and “fertility to increase the natural flora and fauna” (LA01). For example, “working organic matter back into the soil” increases water retention and decreases “bald spots” in the crop (TX16).

Healthy soil has “everything it needs to grow a plant” (TX01), including “minerals and phosphorus” with “trace elements and nitrogen” (TX12) and good color (OK08). It “produce[s] a vigorous and fruitful plant in a timely manner” (TX06) and “absorb[s] and hold water in any season” (TX03). Healthy soil “smells like a garden” (TX14). Soil health is a vessel for “keeping something green and growing year-round by managing the soil at a microbial level” (OK02). Healthy soil has “earthworm activity or the capillaries and the holes left behind" and microorganisms that are "beneficial to the microflora that live in the soil" (TX02, TX03, OK02). Healthy soil has healthy plants (OK10) and expresses "organic matter that is incorporated into the soil fragments and striations and pathways for water infiltration" (OK02).

Healthy Soil has Texture and Structure

Farmers described soil health from the perspective of soil texture and structure. Healthy soil contains both moderately sized "granules and smaller dust like particles in between the granules" (LA01); whereas, unhealthy soil is "nothing but beach sand" (LA01). Healthy soil relies on the limited use of commercial fertilizers and needs "zero inputs" or "amendments" because farmers "give back" to the soil when they plant crops (TX07). Healthy soil has porosity—it "form[s] a ball" and "fall[s] apart when it hits the ground" (TX07). Soil texture is affected by "strip-till and no-till" as "land that is conventionally ploughed is nasty [and] the soil is fine and powdery" (TX04). One farmer measured adequate texture and consistency of the soil particles through a simple test: "If the soil crushes together in your hand, it should fall apart and disperse when it hits the ground" (OK03). Healthy soil will also have good ability for roots to permeate and no hardpan" (TX08) while being able to hold the weight of heavy farm equipment. Healthy, active soil supports a soil base that does not crumble under "stress during a drought" (OK02).

Healthy Soil is a Costly Responsibility

Many of the farmers in our study had a technical understanding of soil health management practices and were willing to take on the costly responsibility. Soil health is a "passion" (OK03), "an inherited responsibility to nourish and maintain" the land so the "benefits of building organic matter and water retention" are effective and visible (OK02). Not keeping the soil healthy is risking his livelihood—"risking everything" (TX09).

How do Wheat Farmers Manage Soil Health?

We found two emergent themes related to how wheat farmers manage soil health: tillage methods and technology implementation.

Tillage Methods

Farmers in our study indicated they implement a variety of tillage methods. Conservation tillage methods were recognized by farmers for the many financial benefits they provide because farmers "can build organic matter and save on operating costs" (OK02). Farmers who have transitioned from conventional tillage methods to reduced tillage methods (strip-till and no-till) have seen profound differences in their land and its production. One farmer noted the difference is "unbelievable" (LA06). Having organic matter from milo and corn back in the ground is important for production (LA01). Another farmer prefers no-till because he has seen it work on farms in his area and "[he] wants to increase the aggregate stability and flocculation" of his soil (LA02). Furthermore, other farmers found that they used a variety of tillage methods based on their yearly needs and regional conditions. For example, one farmer used "strip-till on irrigated land, but conventional on non-irrigated acres" (TX03).

Technology Implementation

Farmers rely heavily on technologies (e.g., heavy equipment, soil testing, fertilizing) to maintain soil health and wheat crop productivity but are highly conscious of soil compaction and fertilization when using heavy equipment. “We have to be into technology; we have to stay up with it, or we get left behind (LA06). Some farmers “take soil samples every year” (TX04, OK08) to maintain nutrients for a healthy crop and “fertilize according to the soil sample” (LA05) to “maintain the microbial activity in the soil” while others do so only as necessary (TX03, OK02). LA05 said he does not consider cutting fertilizer. Limiting “trips across the field” helps with compaction, traffic control, maintaining soil health (TX03), and implementing “fertility programs” designed to aid in soil health management and “increase the natural fauna and flora” (LA01). Farmers implemented crop rotation, measured soil fertility, and monitored soil residue to achieve soil health (TX14), and they maintained healthy soil by monitoring its humus and residue content (TX12). Critical to soil health was maintaining soil “acidity, fertilizer, and compaction” and maintaining soil particle texture to allow for water and nutrient permeation (OK02, OK10).

Why do Wheat Farmers Manage Soil Health?

We found three emergent themes related to why wheat farmers manage soil health: land preservation for future generations, erosion control, and bottom line improvement.

Land Preservation for Future Generations

Farmers value their soil and realize that owning land is a privilege. One farmer was emotional talking about land ownership—“We really do rent this soil from God” (TX05). Topsoil is not renewable (OK06), so maintaining soil health preserves the soil for generations (TX02, TX03). “An increase in yield and a more sustainable ecosystem for the next generation” is important for the continuation of family farming (TX09). Similarly, soil health impacts the future especially if subsequent generations want “to grow up and farm and be successful” (TX02). Preserving and maintaining soil health is a “long-term” endeavor to keep the land in “as good or better shape” as when it was first farmed (TX10) and to preserve the land for future generations “to farm and be successful” (TX12). Sustainability is important for generational farming (TX18, OK03).

Erosion Control

Managing soil health to prevent and control erosion was a frequently mentioned justification for maintaining ideal soil composition. Inherited farmland and diminishing soil contents were closely associated: “There’s going to be so many more generations pass. We cannot let [the soil] all in the rivers and lakes erode so quickly” (TX03). One Oklahoma farmer said, “if we lose any of it, it is gone forever” (OK06). Farmers are focused on “...trying to increase organic matter to keep some cover on the ground to stop wind and water erosion” (OK02) and “reduce the impacts of a hard rain” (LA01). Monitoring and conserving soil nutrients influences soil integrity and resistance to erosion: “Having adequate soil density means we have to build up the various nutrients in the soil to prevent erosion” (TX03). Additionally, strategic conservation management practices are as a means of reducing erosion: “keeping residue on top, ploughing further away from waterways, and planting grass in waterways to maintain them” (TX04). Farmers implemented specific measures (e.g., planting cover crops for root and cover assistance) to control erosion (OK02) because the “primary goal here is to stop erosion” (TX03).

Bottom Line Improvement

It comes down to “money”—it is all about the “bottom line” (OK02). Farmers willing to take financial risks typically see soil health management as “...an investment” (OK03) because “there is no monetary value you can put on knowing you have been a steward of the soil” (TX03). Investment is a strategic decision often based on potential profit—“investment in fertilizers helps with profit gain when crop is sold after harvest” (TX04). Another farmer is simply “...trying to stay in business” with the land and equipment he has (LA01). He said, “if you do not put money in, you won’t get money out” (LA01). Yet, another Louisiana farmer said, “if I am making money, then I am staying in business” (LA02). Farmers choose to invest in land that is producing yields and are willing to sell the land if crop yields decline. “If you don’t get your return on investment like good land should, you have to sell that land and move on” (OK02). The improvement is important long-term (TX11).

What Drives Wheat Farmers’ Interest in Managing Soil Health?

We found three emergent themes related to what drives wheat farmers’ interest in managing soil health: soil health is important, soil health meets landowners’ needs, and soil health is difficult to manage. Overall, wheat farmers we interviewed indicated in question six a neutral to high interest in managing soil health. Most of them were interested in managing soil health and prolonging the life of their soil and its production capability, which has the potential to drive their interest in adopting soil health management practices.

Soil Health is Important

Wheat farmers were interested in managing soil health because soil health is important “to keep the life” in the soil (TX03). Because “anhydrous … was very hard on the microbes,” one farmer switched to no-till (TX04). Another was concerned about exposing his community of 3,000,000 people to a water supply with runoff containing residue from chemicals or herbicide while another switched to no-till to maintain soil health (TX02). Farmers who were more interested in managing soil health recognized the variable nature of soil texture and nutrients throughout their operation. An Oklahoma farmer said minimal inputs is the big thing for him (OK04). One farmer was making efforts to cater to specific portions of his land and was seeking a “total approach to [his] whole farm” (OK02) to improve soil conditions while another was concerned about his family and the generations of farmers to follow him because the generations to come need healthy soil that does not run into water bodies (TX03).

Soil Health Meets Landowners’ Needs

Other farmers were interested in managing soil health because it meets landowners’ needs. Landowners want farmers to “leave the land in better shape” than they found it and do not want the land to be “abused” (TX01). One farmer valued soil health from the perspective of being a “conservationist” of the land and recognized the financial benefits of doing so (LA02). Another farmer’s “father was a champion in soil conservation and conservation of natural resources,” so conservation is a way of life (OK08). Consistent, high production of the soil is how one Oklahoma farmer determined his interest in soil health management practices (OK06). “Deep tillage” along with “crop rotation” was the most beneficial for another’s soil and operation (LA04). Other farmers, however, were knowledgeable about the impact of traditional practices and wanted to manage soil health to obtain higher moisture retention and prevent erosion (TX10).

Soil Health is Difficult to Manage

Three farmers in our study were neutral in their interest to manage soil health. One farmer noted he was neutral because he wanted to "prevent and fight off disease" (TX01) while another one has "tried no-till" but is not always available to spray for weeds or for springtime spraying when there is no wind. It is a big hindrance to be there at the right time, and it is all about timing (TX13). Another farmer who took a neutral stance on managing soil health recognized the financial benefits of reduced tillage, but his goal to achieve "uniformity in the health of his crops" hindered his interest in managing soil health (LA01).

Why do Wheat Farmers Choose to Adopt Soil Health Management Practices?

We found six emergent themes related to why wheat farmers choose to adopt or reject soil health management practices: long-term benefits of soil fertility, improve the bottom line, climatological and environmental, information from neighbors, traditional, and functionality and necessity.

Long-term Benefits of Soil Fertility

Farmers indicated they adopted soil health management practices because they sought prolonged life of their soil and its production capability. Wheat farmers who adopted soil health management practices had no reservations about investing in management practices for the long-term benefits of soil fertility. For example, this mindset is characterized by "I have confidence that reduced tillage produces more yield in comparison to conventional tillage" (TX02) and "I don't mind spending money on input" (TX03). The farmers who adopted soil health management practices did so to invest in the long-term benefits of "putting nutrients back into the soil" (TX03) and of maintaining the generational family operation (TX02). One Texas farmer said he looks at soil health long-term—he wants it in as good or better shape than when his dad gave it to him (TX10). The adopters recognized the necessity to improve and maintain soil health because, for years, farmers had taken from the land without returning anything to the land (TX02). Another farmer is working with planting "cover crops and irrigation" to create an ideal soil environment on the coastal plains (LA01). An innovative farmer is willing to change soil health practices if conditions warrant it. For example, one farmer typically plants wheat in no-till soil, but due to excessive water erosion, he ploughed his field conventionally to evaporate the moisture content (LA01).

Farmers often adopt minimum tillage and cover crop practices to maintain soil integrity and soil residue content (OK02, LA01, TX04). One wheat farmer chose to adopt soil health management practices to make continuous improvements to his current soil health management programs. He said, he "would love to learn more about organic matter and how to improve the organic matter content of my soil" (LA06). Because of this, he works closely with Extension "on a rotational planting program with corn, milo, wheat and soybeans" to monitor the effects on soil health (LA06). Another innovative farmer recognized adopting soil health management practices is how farmers can focus on a "total treatment," including soil health, crop health, equipment costs, and revenue, and not on specific problems and solutions (OK02). Yet, another farmer understood "deep tillage" and "crop rotation" (LA01) were the most beneficial for his soil and operation because he perceived those management practices to be the best way to conserve soil, maintain soil nutrients, and mitigate soil loss from the high amount of annual rainfall in his area.

Improve the Bottom Line

Farmers who had adopted soil health management practices understood the financial risks of innovations but were willing to take them. They recognized the long-term benefit of investing in practical soil conservation techniques and recognized the “dollars in, dollars out” aspect of conservation (OK02). They wanted to keep from spending money on using conventional tillage and “wrecking the soil” (OK02). A Louisiana farmer said that “it is more for the savings of money” (LA02). For another farmer, “reduced tillage” saved “fuel and time” (TX02). One farmer described his motivation for adopting soil health technologies as “self-sustaining [and a] reward for the investment” (TX18). For another farmer, choosing not to adopt soil health management practices was risking everything (TX09). On the other hand, another farmer stayed informed “about conservation” because the topic is interesting and implementing conservation practices “can save money” (LA02).

In contrast, farmers described those who chose not to adopt soil health management practices because they were concerned about “the bottom line at the end of the year” (TX02) and sought to produce wheat in a financially conservative manner, indicating that decisions not to adopt were motivated by finances. For example, a benefit of minimal tillage was simply saving operating costs because of a labor shortage (OK02). More information about the long-term economic risks of soil health management could help these farmers adopt soil health management practices. For example, when farmers are “young farmer[s] and money conscious,” they have to “make money when it comes to crop rotation” (TX03). Because of constrained assets, any uncertainty must be removed prior to adoption. “If I can conserve soil and still have high yields, then I may consider reduced tillage” (LA03). Cover crops are the “future, but the problem is commodity prices” (LA04), which often deters farmers.

Climatological and Environmental

There is a need to adopt soil health practices for microbial sustainability so the soil can withstand the “velocity of rain droplets” and contain a healthy “micro-flora and fungi” (OK02). One farmer chose to adopt soil health management practices prior to other farmers “to increase organic matter to keep the ground covered” (OK02) to help reduce erosion and another to lessen the carbon footprint (TX12). Because of their awareness of risks and benefits, farmers who adopt soil health practices are concerned by “seeing the soil leave” the field from “wind or water erosion” and enjoy “experiment[ing]” with planting mixed species to promote healthy soil (OK02). For example, rainfall in a dry climate prompted one farmer who has cattle to implement cover crops and no-till to reduce livestock and small grains market loss (OK05). No one in the region of OK05 used conventional till much anymore because, to maximize rainfall, they had to use no-till or cover crops. Another farmer said he was a conservationist, and soil conservation interests him (LA02). Immense amounts of rainfall pushed another farmer to use “no-till before it was popular” (OK02). Interestingly, one Louisiana (01) farmer said he “reduce[s] the impacts of a hard rain” by maintaining a certain level of soil surface residue.

Information from Neighbors

Several farmers shared they look to the innovators or early adopters to support an innovation before they adopt because, if an expert or early adopter supports an innovation, they are more likely to act. For example, the advice of an early adopter “to try strip tillage on a quarter section of land” helped another farmer see its benefits when “it rained and there was very little run off” even though the ditch of the neighbor who uses conventional till “was full of water” (OK02). Another farmer noted he noticed his “fields produce better yields” than the “neighbor” who implements conventional tillage practices (LA06). A Louisiana farmer was motivated to adopt soil health management practices because it was a competition with his neighbor for increased yields (LA01). An Oklahoma farmer likes bragging rights at the coffee table when he talks about his crop yields (OK04).

Traditional

Those who have chosen not to adopt soil health management practices could be perceived as late majority or laggards in terms of managing soil health. Farmers who used conventional tillage did so simply to be traditional or because of timing, climate, or land-leveling needs. One farmer said he continued to use conventional practices because that is how he was raised (TX11). Some farmers chose to be traditional and implement practices that are most feasible for their circumstances, and this is especially true for those farmers who are conscious of their limited resources. These farmers adopted soil health management practices “to keep forages on top of the soil for cover as long as weeds and disease are manageable” (OK07) and to do what they need to do to sustain operations (OK01). We found laggard farmers watched their neighbors to see if wheat yields improved before deciding to adopt, indicating they wanted to see it work before choosing to adopt. One Texas farmer had “tried minimum tillage before.” However, “the drawback … is the harvest season is very wet and we end up making large ruts in the field, so we have to plough to level the field back out” (TX15). Another wants to try no-till because of his neighbors’ success but cannot because he “is not able to plough in time to manage weeds and work with rains” (TX13).

Functionality and Necessity

Other farmers adopt out of necessity or functionality—simply because they have no other options. As an example, one farmer shared a waterway for irrigation with neighboring operations and “planted grass” in the waterway adjacent to [his] property to maintain the integrity of the waterway (TX04). Another farmer makes necessary operational decisions to maintain soil integrity due to “extreme” wind and water erosion (OK05). “If a crop is not thriving and profitable, it is time to make a decision about the land that is producing that crop” (OK02). One Texas farmer said he has to do all he can to protect the soil for the next generation because they do not have much—“it’s all shallow” (TX05).

What Information Sources and Communications Mediums do Wheat Farmers Prefer when Receiving Information about Soil Health Management Practices?

In Texas and Oklahoma, farmers most preferred to receive information from Extension specialists and university faculty whose primary job is to disseminate scientific information and from themselves. However, in Louisiana, farmers’ preferred information sources included crop consultants, university faculty, and themselves. County Extension service sponsored field days and demonstrations were farmers’ most preferred communication mediums. Farmers preferred field days and demonstrations due to the visual and hands on representation of soil health management techniques—demonstrations that one “can touch and see” (OK06). At these types of events, farmers can gather and discuss details about technologies and practices with Extension professionals and soil specialists (OK08). “The best way to get people to implement these practices is by seeing the on-farm demonstrations and field days” (TX10). Extension service sponsored field days are a trustworthy way to disseminate scientific information and provide real-time demonstrations to farmers. One Oklahoma farmer said he wants to attend field days “to hear it from someone else” because the neighbors are trying to compete (OK06). Farmers in our study preferred communication channels of information that reflected interpersonal channels because they can “ask questions” (OK03) and “visit with your neighbor or someone you trust for their opinion” (OK06). One farmer appreciates the “turnout” and the ability to hear “thorough explanations” at the field days because he believes “someone is really listening” when gathering in social circles (LA06).

Conclusions

Our study contributes to the literature about the soil health management practices, adoption characteristics, and preferred information sources of wheat farmers in Texas, Oklahoma, and Louisiana, helping to address the need for region-specific information about conservation practices (Dunn et al., 2016; Hamilton et al., 2017; Lavoie et al., 2021). Farmers in our study described healthy soil three ways: healthy soil is a living biome, healthy soil has texture and structure, and healthy soil is a costly responsibility. In addition, they managed soil health using tillage methods and technology implementation (e.g., heavy equipment, soil testing, fertilizing) and did so to preserve the land for future generations, control erosion, and improve their bottom line. Furthermore, farmers were interested in managing soil health for two reasons (soil health is important and soil health meets landowners' needs) and neutral in their interest for one reason (soil health is difficult to manage). Farmers chose to adopt or reject soil health management practices for six reasons: long-term benefits of soil fertility, improve the bottom line, climatological and environmental, information from neighbors, traditional, and functionality and necessity. Texas and Oklahoma farmers' most preferred information sources were Extension specialists, university faculty, and themselves, and Louisiana farmers' most preferred were crop consultants, university faculty, and themselves. Extension-sponsored field days and demonstrations were farmers' most preferred communication mediums.

Discussion

When describing soil health, wheat farmers often focused on organic matter and long-term, sustainable practices, and they used scientific terms to describe the management practices and processes. Healthy soil is resilient, allows root growth, resists erosion, retains moisture, and combines key soil elements, which were part of what Kopittke et al. (2023) describes as a multifunctional soil foundational to a healthy planet. Similar to Jones et al. (2022), Larkin (2015), and Lal (2016), farmers in our study described healthy soil as dark and full of residue with an organic matter that harbors earthworms and maintains a balanced pH. Healthy soil has good structure with a deep topsoil that provides nutrients to plants, and has a complete profile—visual, tactile, and microbial characteristics. A ball of healthy soil will fall apart when it hits the ground, and healthy land comprised of healthy soil does not erode or have hot spots during the summer. It is important to understand how farmers describe healthy soil because, as Pretty (1995) and Vanclay and Lawrence (1994) noted, successful implementation of practices is often dependent on farmers' scientific understanding. Thus, without understanding healthy soil, they may not understand the *why* of soil health management. We recommend Extension Specialists in the South Central United States establish a standard healthy soil description for use when communicating with farmers.

In alignment with suggestions by Mowrer (2020), Sanchez (2019), and Warren (2017), farmers in our study currently managed healthy soil through reduced tillage methods and technology implementations (e.g., heavy equipment, soil testing, fertilizing). Interestingly, cover cropping as a management practice was not an emergent theme in our study, which could indicate the farmers we interviewed did not implement cover crop practices or were not thinking about cover crops at the time of our study. Therefore, aligned with Lavoie et al. (2021), we suggest more region-specific cover-crop resources be available to wheat farmers in the South Central region. Rogers (2003) describes communication as influential when spreading information about a new idea, and knowledge is the first stage in Rogers' innovation-decision process. We recommend more information be delivered through local farmer influencers (Rust et al., 2022) about opportunities for on-farm trialability in local counties (Lavoie et al., 2021) where unique farm and county characteristics are considered (Dunn et al., 2016) and more region-specific data are available about the benefits of conservation practices (Plastina et al., 2020).

Farmers valued the opportunity to work the land and preserve the land for future generations, aligning with Plastina et al. (2020) as two farmers in their study considered "family tradition" important. Farmers we interviewed saw it has their duty to maintain the land for many generations to farm. They were stewards of the land who found motivation in preparing and maintaining the land for their successors and ensuring their heirs can produce crops on the same soil. Family farming was important to these individuals, and they are driven by the idea of generational farming. Only one of the articles we reviewed (Plastina et al., 2020) found family as a reason for adopting conservation practices, so this was a novel finding among the literature we cited. Thus, we recommend exploring the impact of family and family values on farmers' choices to adopt or not adopt conservation practices. Furthermore, farmers in our study used conservation practices to control erosion. Farmers concern with erosion is real, and just like Kopittke et al. (2023) documented, they know erosion is a problem in maintaining healthy soil, healthy humans, and healthy planet. Deng et al. (2022) and Feng (2018) both described no-tillage practices as one way to mitigate erosion.

Wheat farmers in Texas, Oklahoma, and Louisiana chose to adopt or reject soil health management practices for long-term benefits of soil fertility, because of financial, climatological, and environmental factors, based on information from neighbors, because they sought to maintain traditional farming, or because it was necessary to keep farming. Based on the reasons farmers chose to adopt soil health management practices, many of farmers in our study would be classified as innovators or early adopters as defined by Rogers (2003). These groups are adventuresome, influential, knowledgeable about complex technical applications, and hold a positive position within a social system (Rogers, 2003). Innovators and early adopters have the steadfastness and resources to engage in soil health management practices beneficial to soil longevity and improvement. They closely follow experimental or scientific findings, which helps them adopt innovations early and lead change (Rogers, 2003).

Many of the farmers in our study had a scientific understanding of soil and soil health and were leading the adoption of the practices in their social networks, which Abbot et al. (2002), Dunn et al. (2016), Morrison et al. (2017), and Prokopy et al. (2019) described as important to adoption. As Warren et al. (2017) noted, some conservation practices are new in Oklahoma, so those farmers who have adopted a conservation practice would be leaders in adopting the innovation. Because farmers typically trust their peers more than other stakeholders (Ranjan et al., 2019; Rust et al., 2020; Rust et al., 2022), innovative or early adopting wheat farmers who are familiar with the scientific and tactical knowledge of soil health practices are ideal leaders within their networks.

An often-missed group in studying adoption of conservation practices, however, are those farmers who adopt cover crops and discontinue use or those farmers who choose to delay adoption significantly or choose to never adopt cover crops. Those farmers were underrepresented in our sample not by design but because of how we identified our population. Dunn et al. (2016) found self-funded adoption was a predictor of discontinuance, but still little is known about those farmers who choose not to adopt conservation practices. Therefore, we recommend this group be further studied to understand why—why not continue the practice. Reaching this group will most likely be challenging. As Orem et al. (2024) noted in a recent study, response rates among farmers are declining so they are quickly becoming hard-to-reach populations. Because these laggard or non-adopting groups (Rogers, 2003) are already challenging to find and interview, the declining response rates could make them even harder to study.

In addition to studying the laggard and non-adopters, we recommend reaching these individuals through local programming delivered by farmer influencers (Rust et al., 2022) who have adopted and been successful with conservation practices (Lavoie et al., 2021). Consistent with Taylor and Bhasme (2018), we recommend this programming be achieved through workshops, field days, and educational materials that focus more on the science and less on the practice, thereby, providing farmers confidence in discussing soil health through a scientific lens and understanding of the science of why soil health management practices matter. This programming could focus on scientific principles of soil and soil health, on how farmers can know when they have reached the scientific pinnacles of healthy soil, and on perspectives and achievements of peers who possess expertise in soil health practices (Dunn et al., 2016; Lawson et al., 2020; Lavoie et al., 2021; Ranjan et al., 2019; Rust et al., 2022) as well as on the importance of the soil and soil health to the needs of the planet (Kopittke et al., 2024). Information should provide awareness of the benefits for integrating soil health practices into current management practices because some farmers lack the knowledge needed to implement best management practices successfully (Dewald et al., 2018).

According to Rogers (2003), innovations and ideas are better disseminated through social circles. In recent studies, scholars have found social networks are important to adoption and are critical to the dissemination of information (Bruenig, 1991; Hall & Rhoades, 2010; Prokopy et al., 2019; Ranjan et al., 2019; Taku-Forchu, 2023). Farmers described herein preferred gathering in social circles and considered Extension-hosted field days and demonstrations as important sources of information when making decisions about adopting soil health management practices. Face-to-face engagement and peer-to-peer communication have been effective avenues for increasing farmers' knowledge about soil health (Lawson et al., 2020; Rogers, 2003). Thus, an important component of those on-farm demonstrations is the peer-to-peer communication, which is consistent with Jemison et al.'s (2018) findings in that providing opportunities for innovative leaders to engage with laggards or non-adopters is critical to the widespread adoption of innovative practices. We recommend intentional efforts (e.g., targeted communication, educational programming, peer-to-peer communication) to foster adoption of soil health management practices and to mitigate barriers to adoption of soil health innovations. In addition, we recommend regular communication with farmers to determine if changes to their soil management programs are needed and to regularly test and monitor soil conditions, so farmers can make farm-specific decisions (Lavoie et al., 2021).

Furthermore, farmers in our study did not discuss digital platforms much when discussing preferred information sources and communication platforms. Dunn et al. (2016) found there was a difference in early and late adopters in how they prefer information. Therefore, we recommend researchers explore the use of digital media among wheat farmers in the South Central United States to inform ways digital media could be used to encourage adoption. We recommend further study, perhaps a Q methodology study, to explore current communication practices related to conservation practices, stakeholders' preferred types of communication for receiving information, and types of communication materials and educational programs that will close the gap on adoption of soil health management practices in the South Central United States. Those results will assist Extension professionals in delivering scientific-based programs about soil health.

At the same time, we recommend future studies explore the types of adoption and conservation messages that most resonate with Rogers' different adopter groups—this aligns with Dunn et al.'s (2016) recommendations that research has still not explored messaging in the context of conservation practices. Along with this, there is work to be done on information source and source credibility as Rust et al. (2022) studied in Hungary and the UK. Finally, one must question if Rogers' 2003 *Diffusion of Innovations* book should be updated and expanded to include the rapidly changing education and communication landscape. As the use of the internet has become more widespread, there is an opportunity to explore how digital media, including social media and podcasting (Rust et al., 2022), impacts the adoption of on-farm technologies.

References

Ahmed, S. K. (2024). The pillars of trustworthiness in qualitative research. *Journal of Medicine, Surgery, and Public Health, 2,* 100051. https://doi.org/10.1016/j.glmedi.2024.100051.

Arbuckle, J. G., & Ferrell, J. (2012). Attitudes toward cover crops in Iowa: Benefits and barriers. *Iowa State University Extension and Outreach Publications. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1018&context=extension_pubs*

Beattie, P. N., Benge, M., Telg, R. W., & Lundy, L. K. (2022). Assessing Florida early career Extension faculty's adoption of design principles to communicate messages. *Journal of Applied Communications, 106*(3), 2. https://doi.org/10.4148/1051-0834.2425

Bruening, T. H. (1991). Communicating with farmers about environmental issues. *Journal of Applied Communications, 75*(1). https://doi.org/10.4148/1051-0834.1489

Carlisle, L. (2016). Factors influencing farmer adoption of soil health practices in the United States: A narrative review. *Agroecology and Sustainable Food Systems, 40*(6), 583–613. https://doi.org/10.1080/21683565.2016.1156596

Canales, E., Bergtold, J. S., & Williams, J. R. (2018). Modeling the choice of tillage used for dryland corn, wheat and soybean production by farmers in Kansas. *Agricultural and Resource Economics Review, 47*(1), 90–117.

Creswell, J. W., & Guetterman, T. C. (2021). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Pearson.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Sage publications.

de Medeiros Barbosa, V. F. A. (2015). Planting. In F. Santos, A. Borém, & C. Caldas (Eds.), *Sugarcane* (pp. 35–51). Academic Press.

Deng, F., Wang, H., Xie, H., Bao, X., He, H., Zhang, X., & Liang, C. (2022). Low-disturbance farming regenerates healthy deep soil toward sustainable agriculture - evidence from long-term no-tillage with stover mulching in Mollisols. *Science of The Total Environment*, *825*, 153929. https://doi.org/10.1016/j.scitotenv.2022.153929

Dewald, S., Leggette, H., Murphrey, T. P., Berthold, A., & Wagner, K. (2018). Communicating to landowners in the Texas Little River watershed: A descriptive analysis of their communication preferences for receiving water-related information. *Journal of Agricultural Education*, *59*(2), 343–369. https://doi.org/10.5032/jae.2018.02343

Dewald, S., Murphrey, T., Leggette, H., Berthold A., & Wagner, K. (2019) Landowner adoption of water quality best management practices: Motivations and barriers. *Journal of Extension, 57*(5). https://joe.org/joe/2019october/pdf/JOE_v57_5rb4.pdf

Dunn, M., Ulrich-Schad, J. D., Prokopy, L. S., Myers, R. L., Watts, C. R., & Scanlon, K. (2016). Perceptions and use of cover crops among early adopters: Findings from a national survey. *Journal of Soil and Water Conservation*, *71*(1), 29–40. https:// doi:10.2489/jswc.71.1.29

Feng, J., Li, F., Zhou, X., Xu, C., Ji, L., Chen, Z., & Fang, F. (2018). Impact of agronomy practices on the effects of reduced tillage systems on CH4 and N2O emissions from agricultural fields: A global meta-analysis. *PloS one, 13*(5), e0196703. https://doi.org/10.1371/journal.pone.0196703

Fraenkel, J. R., Wallen, N. E. & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). McGraw-Hill.

Gibson, K. E., Lamm, A. J., & Lamm, K. W. (2020). Identifying audience needs to effectively communicate about the cost of implementing sustainable farming practices. *Journal of Applied Communications, 104*(3). https://doi.org/10.4148/1051-0834.2334

Hall, K., & Rhoades, E. (2010). Influence of subjective norms and communication preferences on grain farmers' attitudes toward organic and non-organic farming. *Journal of Applied Communications, 94*(3). https://doi.org/10.4148/1051-0834.1192

Hamilton, A. V., Mortensen, D. A., & Allen, M. K. (2017). The state of the cover crop nation and how to set realistic future goals for the popular conservation practice. *Journal of Soil and Water Conservation*, *72*(5), 111A–115A.

Hutchinson, R. L. (2012). Introduction. In *Louisiana conservation tillage handbook* (pp. 1–3). Louisiana State University Agriculture Center.

Ingram, J. (2008). Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of farmer and advisor views. *Journal of Environmental Management*, *86*(1), 214–228. https://doi.org/10.1016/j.jenvman.2006.12.036

Jemison, J. M., Welcomer, S., Kersbergen, R., & Majewski, C. (2018). Word cloud analysis of early adopter no-till farmer interviews. *Journal of Extension*, *56*(3). https://www.joe.org/joe/2018june/pdf/JOE_v56_3rb3.pdf

Jones, C., Olsen-Rutz, K., Miller, P., Zabinsky, C., & Tallman, S. (2022). *Cover crops: Soil health*. MSU Extension | Montana State University. https://apps.msuextension.org/publications/pub.html?sku=EB0238

Kopiyawattage, K., Warner, L., & Roberts, T. G. (2018). Information needs and information-seeking behaviors of urban food farmers: Implications for urban extension programs. *Journal of Agricultural Education, 59*(3), 229–242. https://doi: 10.5032/jae.2018.03229

Lal, R. (2015). Sequestering carbon and increasing productivity by conservation agriculture. *Journal of Soil and Water Conservation*, *70*(3), 55A–62A. https://doi: 10.2489/jswc.70.3.55a

Lal, R. (2016). Soil health and carbon management. *Food and Energy Security*, *5*(4), 212–222. https://doi: 10.1002/fes3.96

Larkin, R. P. (2015). Soil health paradigms and implications for disease management. *Annual Review of Phytopathology, 53*(1), 199–221. https://doi.org/10.1146/annurev-phyto-080614-120357

Lavoie, A. L., Dentzman, K., & Wardropper, C. B., (2021). Using diffusion of innovations theory to understand agricultural producer perspectives on cover cropping in the inland Pacific Northwest, USA. *Renewable Agriculture and Food Systems, 36*(4), 384–395. https://doi:10.1017/S1742170520000423

Lawson, K., Kent, K., Rampold, S., Telg, R. W., & McLeod-Morin, A. (2020). Impacting agriculture and natural resource policy: County commissioners' decision-making behaviors and communication preferences. *Journal of Applied Communications, 104*(1). https://doi.org/10.4148/1051-0834.2307

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage Publications.

Louisiana State University Ag Center. (2018). *2018 Highlights of Louisiana Agriculture*. LSU Extension Service. https://www.lsuagcenter.com/~/media/system/d/7/8/c/d78c489f32e9ccde2e2eb7128e14ccb8/highlights%20of%20louisiana%20agriculture%202018pdf.pdf

Kopittke, P. M., Minasny, B., Pendall, E., Rumpel, C., & McKenna, B. A. (2023). Healthy soil for healthy humans and a healthy planet. *Critical Reviews in Environmental Science and Technology, 54*(3), 210–221. https://doi.org/10.1080/10643389.2023.2228651

Maharjan, B., Das, S., & Acharya, B. S. (2020). Soil health gap: A concept to establish a benchmark for soil health management. *Global Ecology and Conservation*, *23*. https://doi:10.1016/j.gecco.2020.e01116

Merriam, S. B., & Tisdell, E.J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass, Inc.

McCorkle, C. M. (1989). Toward a knowledge of local knowledge and its importance for agricultural RD&E. *Agriculture and Human Values*, *6*, 4–12.

McGuire, E., Rietveld, A. M., Crump, A., & Leeuwis, C. (2022). Anticipating gender impacts in scaling innovations for agriculture: Insights from the literature. *World Development Perspectives*, *25*, 100386. https://doi.org/10.1016/j.wdp.2021.100386

Morrison, M., Hine, D., & D'Alessandro, S. (2017). Communicating about climate change with farmers. *Oxford Research Encyclopaedia of Climate Science.* https://oxfordre.com/climatescience/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-415

Mowrer, J. (2020, August 14). Texas row crops newsletter. *Agrilife.org*. https://agrilife.org/texasrowcrops/2020/08/14/when-it-comes-to-cover-crops-in-texas-timing-is-key/.

National Agricultural Statistics Service. (2020). *National quick stats: Wheat 2019* [Data Set]. United States Department of Agriculture, National Agricultural Statistics Service. https://quickstats.nass.usda.gov/results/CD05A5D0-97A8-3714-B8FA-14D61E1F14CC

National Agricultural Statistics Service Texas Field Office. (2020). *Texas quick stats: Wheat 2019* [Data Set]. United States Department of Agriculture, National Agricultural Statistics Service. https://quickstats.nass.usda.gov/results/32C01974-95FA-378E-82BB-17CF553B6121

Norgaard, R. B. (1984). Traditional agricultural knowledge: Past performance, future prospects, and institutional implications. *American Journal of Agricultural Economics*, *66*(5), 874–878. https://www.jstor.org/stable/1241018

Orem, M. (2023). *Cultivating credibility: An examination of information sources that U.S. wheat producers trust and their intent to adopt scientific information in the context of tillage and cover crop practices* [Master's thesis]. Texas A&M University.

Park, J., Farmer, P., Bailey, A., Keatinge, J. D. H., Rehman, T. U., & Tranter, R. (1997). Integrated arable farming systems and their potential uptake in the UK. *Journal of Farm Management*, *9*(10), 483–494.

Patton, M. (2002). *Qualitative research and evaluation methods* (3rd ed.). Sage Publications, Inc.

Plastina, A., Liu, F., Miguez, F., & Carlson, S. (2020). Cover crops use in Midwestern US agriculture: perceived benefits and net returns. *Renewable Agriculture and Food Systems, 35*(1), 38–48. https://doi.10.1017/S1742170518000194

Pretty, J. N. (1995) Regenerating agriculture. Policies and practice for sustainability and self-reliance. *Earthscan*.

Prokopy, L. S., Floress, K., Arbuckle, J. G., Church, S. P., Eanes, F. R., Gao, Y., ... & Singh, A. S. (2019). Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature. *Journal of Soil and Water Conservation*, *74*(5), 520–534. https://doi:10.2489/jswc.74.5.520

Ranjan, P., Church, S. P., Floress, K., & Prokopy, L. S. (2019). Synthesizing conservation motivations and barriers: What have we learned from qualitative studies of farmers' behaviors in the United States? *Society & Natural Resources*, *32*(11), 1171–1199. https://doi.org/10.1080/08941920.2019.1648710

Reimer, A. P., Thompson, A. W., & Prokopy, L. S. (2012a). The multi-dimensional nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. *Agriculture and Human Values 29*, 29–40.

Reimer, A. P., Weinkauf, D. K., & Prokopy, L. S. (2012b). The influence of perceptions of practice characteristics: an examination of agricultural best management practice adoption in two Indiana watersheds. *Journal of Rural Studies 28*, 118–128.

Rogers, E. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Rust, N. A., Ptak, E. N., Graversgaard, M., Iversen, S., Reed, M. S., de Vries, J. R., ... & Dalgaard, T. (2020). Social capital factors affecting uptake of sustainable soil management practices: A literature review [version 2; peer review: 2 approved]. *Emerald Open Research*, *2*(8). https://doi.org/10.35241/emeraldopenres.13412.2

Rust, N. A., Stankovics, P., Jarvis, R. M., Morris–Trainor, Z., de Vries, J. R., Ingram, J., Mills, J., Glikman, J. A., Parkinson, J., Toth, Z., Hansda, R., Mcmorran, R., Glass, J., & Reed, M. S. (2022). Have farmers had enough of experts? *Environmental Management*, *69*(1), 31–44. https://doi.org/10.1007/s00267-021-01546-y

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET*, *5*(2), 14–23.

Saldukaitė, L., Šarauskis, E., Zabrodskyi, A., Adamavičienė, A., Buragienė, S., Kriaučiūnienė, Z., & Savickas, D. (2022). Assessment of energy saving and GHG reduction of winter oilseed rape production using sustainable strip tillage and direct sowing in three tillage technologies. *Sustainable Energy Technologies and Assessments*, *51*, 101911. https://doi.org/10.1016/j.seta.2021.101911

Sanchez, I. I., Fultz, L. M., Lofton, J., & Haggard, B. (2019). Soil biological response to integration of cover crops and nitrogen rates in a conservation tillage corn production system. *Soil Science Society of America Journal*, *83*(5), 1356–1367. https://doi.org/10.2136/sssaj2019.02.0051

Sawadgo, W. P. M., Zhang, W., & Plastina, A. (2021). What drives landowners' conservation decisions? Evidence from Iowa. *Journal of Soil and Water Conservation*, *76*(3), 211–221.

Scott, S., & McGuire, J. (2017). Using diffusion of innovation theory to promote universally designed college instruction. *International Journal of Teaching and Learning in Higher Education*, *29*(1), 119–128. https://files.eric.ed.gov/fulltext/EJ1135837.pdf

Seevers, B., & Graham, D., (2012). *Education through Cooperative Extension* (3rd ed.). University of Arkansas Bookstore.

Simin, M. T., & Janković, D. (2014). Applicability of diffusion of innovation theory in organic agriculture. *Economics of Agriculture*, *61*(2), 517-529.

Taku-Forchu, N., Qu, S., Lambert, M. D., Retallick, M., Ulmer, J. D., & Opit, G. P. (2023). Maize farmers' use, preference, and trustworthiness of information sources and communication channels in Dormaa, Ghana: A gender comparison. *Journal of Applied Communications*, *107*(3). https://doi.org/10.4148/1051-0834.2479

Taylor, M., & Bhasme, S. (2018). Model farmers, extension networks and the politics of agricultural knowledge transfer. *Journal of Rural Studies*, *64*, 1–10. https://doi: 10.1016/j.jrurstud.2018.09.015

Texas Department of Agriculture. (2017). *Texas ag stats*. https://www.texasagriculture.gov/About/TexasAgStats.aspx

Turmel, M.-S., Speratti, A., Baudron, F., Verhulst, N., & Govaerts, B. (2015). Crop residue management and soil health: A systems analysis. *Agricultural Systems*, *134*, 6–16. https://doi: 10.1016/j.agsy.2014.05.009

USDA National Agricultural Statistics Service. (2019). *2019 grain and feed agricultural statistics* (Chapter 1). https://www.nass.usda.gov/Publications/Ag_Statistics/2019/chapter01.pdf

USDA National Agricultural Statistics Service Oklahoma Field Office. (2021). *2021 State agriculture overview*. United States Department of Agriculture, National Agricultural Statistics Service. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=OKLAHOMA

University of Arkansas Research and Extension. (2020). The economic contributions and impacts of U.S. food, fiber, and forest industries. Department of Agriculture. https://economic-impact-of-ag.uada.edu/oklahoma/

Vanclay, F., & Lawrence, G. (1994). Farmer rationality and the adoption of environmentally sound practices: A critique of the assumptions of traditional agricultural extension. *European Journal of Agricultural Education and Extension*, *1*(1), 59–90. https://doi.org/10.1080/13892249485300061

Wade, T., Claassen, R., & Wallander, S. (2015). *Conservation-practice adoption rates vary widely by crop and region* (Economic Information Bulletin Number 147). United States Department of Agriculture. https://www.ers.usda.gov/webdocs/publications/44027/56332_eib147.pdf?v=42403

Warren, J., Meeks, K., & Edwards, J. (2017). *Benefits of using cover crops in Oklahoma no-till* (Id: PSS-2161) [Fact Sheet]. Oklahoma State University Extension. https://extension.okstate.edu/fact-sheets/benefits-of-using-cover-crops-in-oklahoma-no-till.html

Wehmeyer, H., Malabayabas, A., San, S. S., Thu, A. M., Tun, M. S., Thant, A. A., & Connor, M. (2022). Rural development and transformation of the rice sector in Myanmar: Introduction of best management practices for sustainable rice agriculture. *Outlook on Agriculture*, 00307270221086008.

Wuellner, M. R., Gates, R., Turner, B., & Menendez, H. M. (2018). Shaping soil watershed stewardship through combined producer and influencer education: A pilot program. *The Journal of Extension*, *56*(6), 3. https://doi.org/10.34068/joe.56.06.03

Yang, H., Xiao, Y., He, P., Ai, D., Zou, Q., Hu, J., Liu, Q., Huang, X., Zheng, T., & Fan, G. (2021). Straw mulch-based no-tillage improves tillering capability of dryland wheat by reducing asymmetric competition between main stem and Tillers. *The Crop Journal*. https://doi.org/10.1016/j.cj.2021.09.011