Title

Supporting a transition to a regenerative agriculture in the Corn Belt: Grassroots and top-down approaches to encouraging farmer adoption of regenerative farming practices

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Publication Date
2023

Peer reviewed|Thesis/dissertation

Supporting a Transition to a Regenerative Agriculture in the Corn Belt; Grassroots and Top-down Approaches to Encouraging Farmer Adoption of Regenerative Farming Practices

By
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DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Geography

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

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2023

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Dissertation Abstract

This dissertation examines the barriers to and drivers of a transition to regenerative agriculture in the US Corn Belt through bottom-up and top-down approaches to addressing change. Working closely with non-governmental organizations to develop and implement the research, I draw on surveys, interviews, focus groups, participant observation, and document analysis to explore farmer decision making in two contexts: a formal farmer network, Practical Farmers of Iowa (PFI), and in the adoption of small grains, or cereal crops such as barley, oats, rye, and wheat. In the first part of the dissertation, composed of Chapters 1 and 2, I examine the role of PFI in the adoption of a range of conservation practices among member farmers. In the second part, composed of Chapter 3, I focus on one important conservation practice — diversification through small grain production — and explore a range of factors that influence farmers' decision making in this context. I pay particular attention to farm policy, an often-neglected element in understanding farmer decision making. Several key findings emerged from the dissertation. First, formalized peer networks of farmers can play a significant role in the adoption of conservation practices, evidenced by a large and longstanding formal farmer network, PFI. Second, in-person ways of participating in networks like PFI can have a greater impact on the adoption of conservation practices compared to independent formats due to the ability to have side conversations with other farmers, ask questions, and observe results. Third, PFI has created a recipe for collaborative, farmer-driven research that relies on a diverse membership, autonomous functioning, culture of openness, and non-ideological nature. Fourth, when considering one specific conservation practice, the adoption of small grains, a multitude of factors influence farmers' decision making; markets are the most important, and the specific Farm Bill programs available for small grains are comparatively less important. Just as there are a multitude of factors that impact farmer decision making, there are a multitude of actions that must be taken to support farmers to transition to regenerative agriculture including market

development and processing infrastructure for a diverse array of farm products, sourcing commitments from food companies to purchase local products grown using conservation practices, improved varieties and practices for conservation agriculture, risk management tools and cost share that incentivize diversification, and peer support and education on alternative practices through farmer networks.

Dissertation Keywords: Corn Belt, diversification, conservation practices, farmer networks, small grains, farm policy

Acknowledgements: I am grateful to my family for motivating me to come home to do this work after almost two decades away, to my project collaborators for making this work possible, to my committee members Dr. Mark Cooper, Dr. Linda Prokopy, and Dr. Liz Carlisle for their feedback and support, and to my advisor, Dr. Ryan Galt, for always pushing me to think further and communicate my work more effectively.

Dissertation Introduction

This dissertation research seeks to understand the drivers of and barriers to a transition to regenerative agriculture in the Corn Belt. In the region — entrenched in industrial farming practices that hurt farmers, consumers, rural communities, and the land — a transition away from simplified corn and soybean production requires creative, collaborative, and pragmatic thinking and identification of solutions. Throughout this research, I pay particular attention to two prongs of an approach to changing farmer behavior: grassroots efforts propelled by farmers through a study of formal farmer networks, and top-down change through farm policy in a study of the adoption of small grains in corn and soybean systems. A transition to regenerative agriculture requires bottom-up approaches that place farmers in the driver's seat of a transition. At the same time, top-down approaches address entrenched structural barriers that individual farmers alone cannot overcome. Institutional change, in parallel to grassroots efforts, is required to create an enabling environment for a transition to regenerative agriculture.

I approach this research through an interdisciplinary, mixed methods, and participatory framework. Using literatures from agrarian political economy, political ecology, rural sociology, and the biophysical sciences of agriculture, I examine the individual, operational, social, structural, and biophysical factors that influence farmer decision making around the use of conservation practices and diversification. Working closely with non-governmental organizations (NGOs) to develop and implement the research, I draw on surveys, interviews, focus groups, participant observation, and document analysis to explore farmer decision making in the Corn Belt.

The social sciences of agriculture require a diverse set of knowledges that are both transdisciplinary, crossing the natural and social sciences, and interdisciplinary, crossing disciplines within the social sciences. I have chosen to focus on the fields of geography, political economy, sociology, agronomy, and agroecology, fields that are essential to understanding how to shift our systems of agricultural production towards ones that regenerate soils, enhance ecological complexity, and contribute to a vibrant rural economy. The integration of these fields is essential for a new kind of science, one that transcends disciplinary boundaries, generating a holistic understanding of complex research questions (Robbins, 2015; Reimer et al., 2014).

Employing a participatory and applied approach, I paired with project partners to conduct each part of my dissertation research.[1] Throughout the research, I positioned myself alongside research participants and community partners as co-creators of the knowledge needed to transform agriculture in our region. In the first phase, I partnered with the farmer-led NGO Practical Farmers of Iowa (PFI), whose staff identified a general research question useful to their work, and collaborated with me to develop a research plan, formulate interview questions, interpret results, and compile findings. As a case study on their organization, the results were immediately relevant to their staff, funders, and membership, in addition to other farming organizations and the agencies that support them. In the second part of the dissertation, I partnered with two agricultural NGOs in the Upper Midwest engaged in regenerative agriculture: the Michael Fields Agricultural Institute and the Artisan Grains Collaborative. The overarching research question for this phase originated from a group of farmers and relevant stakeholders in the Midwestern grain value chain at a farming conference, and the project team helped to develop the survey, participate in focus groups, gave feedback on the results, and distributed final outputs to their constituents and partners. Together we formed a project advisory council made up of farmers and key experts and decision makers in the small grain chain in the region who helped guide the survey, interview, and focus group questions, interpret the results, and formulate the recommendations.

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[1] While the project as a whole is shared, because I have been the lead on each project, and the conclusions within and across studies I have drawn are my own, I use "I" throughout the introduction and conclusion.

In the first part, composed of Chapters 1 and 2, I focus on one important *factor* in farmer decision making — the role of the unique PFI network in the adoption of a *range of conservation practices* among member farmers in the Corn Belt. In the second part of the dissertation, composed of Chapter 3, I focus on one important *conservation practice* – diversification through small grain production, and explore a *range of factors* that influence farmers' decision making in this context. I pay particular attention to farm policy, an often-neglected element in understanding farmer decision making.

Each of these chapters is a stand-alone article and can be read in any order. The first two chapters shine a light on peer-to-peer networks as a key resource driving farmers to transition to regenerative agriculture[2]. The democratic sharing of knowledge, arguably the basis of social transformation (Wainwright, 1994), is vital for a large-scale shift in the paradigm and practice of agriculture. Given the complexity of agroecological conditions, this knowledge must be tailored to local conditions including climate, soil type, topography, and local markets (Duru et al., 2015). Yet, a traditional lack of research on place-based, agroecological practices within land grant universities, along with a de-valuing and erosion of farmer-generated knowledge, has led to a gap in knowledge, experience, and skills of sustainable practices in the US (Kloppenburg, 1991). This technical gap, along with a lack of social support structures to encourage adoption, are key barriers facing farmers (Duram, 2000; Iles and Marsh, 2012) that can be addressed by bottom-up solutions.

The third chapter highlights a mostly forgotten element of rotations in the Corn Belt with scant social science literature addressing its disappearance — small grains. These cereal crops, including barley, oats, wheat, triticale, and rye, are integral components of diversified farming

[2] I use the term "regenerative" throughout to refer to agricultural systems, and "conservation" and "diversification" to refer to the specific practices I focus on in each chapter. The term "regenerative" is the ability to not only conserve or sustain, but restore soil health and water quality (Rhodes, 2017), and encompasses both conservation and diversification, as well as other practices.

systems due to their use as a cash crop occupying a temporal niche in northern cropping systems. Harvested at different times of the year than corn and soybeans, small grain production covers the ground for more of the year, supporting improved soil health and water retention (Basche et al., 2016; Janovicek et al., 2021), opens new market opportunities for enterprise diversity (Carlisle, 2014), and supports the integration of livestock (Muckey, 2018). Despite their potential, few farmers grow small grains in the Upper Midwest, and the planting of most small grains has declined over the last century in the region. Understanding why farmers' do and do not grow small grains is critical to providing recommendations on how farmer networks, Cooperative Extension, agricultural support organizations, and government agencies can support farmers to adopt. Policies, in particular, have the potential to support or to undermine conservation practices (Iles and Marsh, 2012), such as farm bill conservation programs (Reimer and Prokopy, 2014), federal crop insurance (Beckie et al., 2019; Fleckenstein et al., 2020), and price supports (Graddy-Lovelace and Diamond, 2017). Due to the lack of attention to policy factors in the field of adoption research, and their potential impact, I focus on each of these policy levers throughout the chapter.

Several key findings emerge from this dissertation. First, formalized peer networks of farmers can play a significant role in the adoption of conservation practices, evidenced by the large and longstanding formal farmer network, PFI. Second, in-person ways of participating in networks like PFI can have a greater impact on the adoption of conservation practices compared to independent formats due to the ability to have side conversations with other farmers, ask questions, and observe results. Third, PFI has created a recipe for collaborative, farmer-driven research that relies on a diverse membership, autonomous functioning, culture of openness, and non-ideological nature. And fourth, when considering one specific conservation practice, the adoption of small grains, a multitude of factors influence farmers' decision making; markets are the most important, and the specific Farm Bill programs available for small grains are comparatively less important.

I am grateful to be able to work with the talented and motivated individuals that joined me on each part of this research to build upon our collective understandings of how to create lasting change in the Corn Belt, an area in which my family has lived for generations. I believe that each of the topics of study in this dissertation, formal farmer networks and Farm Bill programs, have a significant role to play in the creation of an agricultural landscape that I can feel proud to call my home.

References

Basche, A.D., Kaspar, T.C., Archontoulis, S.V., Jaynes, D.B., Sauer, T.J., Parkin, T.B., Miguez, F.E., 2016. Soil water improvements with the long-term use of a winter rye cover crop. Agricultural Water Management 172, 40–50. https://doi.org/10.1016/j.agwat.2016.04.006

Beckie, H.J., Smyth, S.J., Owen, M.D.K., Gleim, S., 2019. Rewarding Best Pest Management Practices via Reduced Crop Insurance Premiums [WWW Document]. International Journal of Agronomy. https://doi.org/10.1155/2019/9390501

Carlisle, L., 2014. Diversity, flexibility, and the resilience effect: lessons from a social-ecological case study of diversified farming in the northern Great Plains, USA. Ecology and Society 19. https://doi.org/10.5751/ES-06736-190345

Duram, L., 2000. Agents' perceptions of structure: How Illinois organic farmers view political, economic, social, and ecological factors. Agriculture and Human Values 17, 35–48.

Duru, M., Therond, O., Fares, M., 2015. Designing agroecological transitions; A review. Agronomy for sustainable development.

Fleckenstein, M., Lythgoe, A., Lu, J., Thompson, N., Doering, O., Harden, S., Getson, J.M., Prokopy, L., 2020. Crop insurance: A barrier to conservation adoption? J. Environ. Manage. 276, 111223. https://doi.org/10.1016/j.jenvman.2020.111223

Graddy-Lovelace, G., Diamond, A., 2017. From supply management to agricultural subsidies—and back again? The U.S. Farm Bill & agrarian (in)viability. Journal of Rural Studies 50, 70–83. https://doi.org/10.1016/j.jrurstud.2016.12.007

Iles, A., Marsh, R., 2012. Nurturing Diversified Farming Systems in Industrialized Countries: How Public Policy Can Contribute. Ecology and Society 17, 42. https://doi.org/10.5751/ES-05041-170442

Janovicek, K., Hooker, D., Weersink, A., Vyn, R., Deen, B., 2021. Corn and soybean yields and returns are greater in rotations with wheat. Agronomy Journal 113, 1691–1711. https://doi.org/10.1002/agj2.20605

Kloppenburg, J., 1991. Social Theory and the De/Reconstruction of Agricultural Science: Local Knowledge for an Alternative Agriculture. Rural Sociology 56, 519–548. https://doi.org/10.1111/j.1549-0831.1991.tb00445.x

Muckey, E., 2018. Small Grains in Minnesota: Assessing the Feasibility of Local Supply Chains (Report).

Robbins, P. 2015. Paul Robbins and the Ecology in Political Ecology. Retrieved Dec 11, 2020, from https://www.youtube.com/watch?v=E1QkulKOZ4c

Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P., 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, 520–534. https://doi.org/10.2489/jswc.74.5.520

Reimer, A., Thompson, A., Prokopy, L.S., Arbuckle, J.G., Genskow, K., Jackson-Smith, D., Lynne, G., McCann, L., Morton, L.W., Nowak, P., 2014. People, place, behavior, and context: A research agenda for expanding our understanding of what motivates farmers' conservation behaviors. Journal of Soil and Water Conservation 69, 57A-61A. https://doi.org/10.2489/jswc.69.2.57A

Reimer, A.P., Prokopy, L.S., 2014. Farmer Participation in U.S. Farm Bill Conservation Programs. Environmental Management 53, 318–332. https://doi.org/10.1007/s00267-013-0184-8

Rhodes, C.J., 2017. The Imperative for Regenerative Agriculture. Science Progress 100, 80–129. https://doi.org/10.3184/003685017X14876775256165

Wainwright, H., 1994. Arguments for a new left: answering the free-market right. Blackwell, Oxford, UK ; Cambridge, Mass., USA

Chapter 1 The adoption of conservation practices in the Corn Belt: The role of one formal farmer network, Practical Farmers of Iowa

Asprooth, L., Norton, M., Galt, R.

Abstract

Substantial evidence has shown that involvement in peer-to-peer farming networks influences whether a farmer decides to try a new practice. Formally organized farmer networks are emerging as a unique entity that blend the benefits of decentralized exchange of farmer knowledge within the structure of an organization providing a variety of sources of information and forms of engagement. We define formal farmer networks as farmer networks with a distinct membership and organizational structure, leadership that includes farmers, and an emphasis on peer-to-peer learning. This study complements existing ethnographic research on the benefits of organized farmer networking by examining farmers in one longstanding formal farmer network, Practical Farmers of Iowa. Using a nested, mixed-method research design, we analyzed survey and interview data to understand how participation and forms of engagement in the network are associated with the adoption of conservation practices. Responses from 677 farmers from a regular member survey disseminated by Practical Farmers of Iowa in 2013, 2017, and 2020 were pooled and analyzed. GLM binomial and ordered logistic regression results indicate that greater participation in the network, particularly through in-person formats, has a strong and significant association with greater adoption of conservation practices. Logistic regression results show that building relationships in the network is the most important variable for predicting whether a farmer reported adopting conservation practices as a result of participation in PFI. In-depth interviews with 26 surveyed member farmers revealed that PFI supports farmers to adopt by providing information, resources, encouragement, confidence building, and reinforcement. In-person learning formats were more important to farmers relative to independent formats because they were able to have side conversations with other farmers, ask questions, and observe results. We conclude that formal networks are a promising way to expand the use of conservation practices, particularly through targeted efforts to increase relationship building in the network through face-to-face learning opportunities.

Keywords: Peer-to-peer networks, Formal farmer networks, Adoption, Agriculture, Conservation practices, Corn Belt

1. Introduction

Agriculture in the Corn Belt is dominated by industrial farming practices that have resulted in serious damages to the health of farmers, the environment, and rural communities. Regenerative agricultural practices that increase cropping diversity while using fewer chemical inputs and conserving soil and water resources are proven to be equally as productive as conventional systems while delivering greater economic and environmental benefits (Cruse et al. 2010; Davis et al. 2012; Dainese et al. 2019; Hunt et al. 2020; Tamburini et al. 2020). Despite these benefits, conservation practices are still relatively rare in the Midwest. In Iowa, the US state that produces the most corn, hogs, and eggs (Thessen et al. 2020), only 11% of cropland operations use cover crops, and 34% use conservation tillage, two critical conservation practices (USDA NASS 2017).

A farmers' decision to adopt a conservation practice is influenced by a complex and interconnected set of social, economic, geographical, environmental, and agroecological factors which have been documented in a large empirical literature (Prokopy et al. 2008; Baumgart-Getz et al. 2012; Carlisle 2016; Prokopy et al. 2019). Of these factors, how and through whom information about a conservation practice reaches a farmer can impact whether they choose to adopt. Diffusion of innovation theory (Rogers 2003) and social network theory (Prell 2012) propose that an individual's social network is central to the diffusion of new ideas and practices. Information about innovations is spread through social networks and the presence of specific individuals or actors within one's network, and the information flowing through it, provide additional explanation as to whether an individual adopts a new practice (Wellman 1983; Valente 1996; Rogers 2003).

Within an individual's network, connections with peers are particularly consequential to whether one adopts a new practice. Explained through the theory of social learning, or transmitting knowledge from peer-to-peer through interpersonal communication, individuals learn best by observing and replicating the behavior of others (Bandura 1977). Information diffused through interpersonal channels allows for the individual to observe and validate results, and to ask questions to decrease uncertainty about the practice (Ban 1981; Rogers 2003). As a result, an individual is more likely to adopt a new practice when information about the practice comes from someone they know and trust and who may have already tested the practice (Foster and Rosenzweig 1995; Rogers 2003; Granovetter 2005). These theories are supported by a large empirical literature in agriculture showing that farmers who are better connected to other adopters and grassroots organizations promoting adoption are more likely to adopt new practices (Prokopy et al. 2008; Baumgart-Getz et al. 2012; Carlisle 2016).

In addition to social learning, farmer networks provide mutual support and motivation to go against established norms in agriculture (Bell 2004; Kroma 2006; Gosnell et al. 2019). More broadly, participating in a social network can instill social pressure to conform to the norms of the group (Ajzen 1991; Montgomery and Casterline 1996; Hogset and Barrett 2010). Social networks of farmers are particularly important for diffusing information on alternative agricultural practices that may not be available through traditional research and extension (Kroma 2006), and for sharing local knowledge about conservation practices that are more information-intensive and site-specific compared to simplified industrial practices (Hassanein and Kloppenburg 1995; Lyon et al. 2011; Iles and Marsh 2012).

Social networks in agriculture can take many forms and much existing research has focused on personal communication networks of farmers through social network analysis (Garbach and Morgan 2017, Levy and Lubell 2018) and ethnographies of formal and informal networks (Hassanein 1999, Bell 2004, Warner 2007, Wypler 2019). Fewer studies have examined organized or formalized farmer-to-farmer networks, which we identify as a unique construct. In this paper, we look specifically at formal farmer networks to understand the significance of this type of peer organization in catalyzing farmers to adopt conservation practices in the Corn Belt.

2. Formal farmer networks

A handful of studies have examined the role of formal agricultural networks in the context of social change in agriculture (Bell 2004; Trauger 2009; Barbercheck et al. 2014; Pape and Prokopy 2017; Šūmane et al. 2018). Within these studies, no shared definition of what constitutes a formal farmer network exists and only two differentiate between types of farmer networks. Pape and Prokopy (2017) define formal and informal social networks broadly where formal networks are structured organizations with defined roles and purposes (e.g., a club, church body, or team of coworkers) and informal networks are unstructured interrelations between individuals acting on their own terms, without centralized organization or planning (e.g., family, neighbors, and friends). Šūmane et al. (2018) specify formal knowledge networks in agriculture as formal institutions with a structured agenda, that receive public funding, and that circulate formal knowledge (e.g., universities, advisory services) as opposed to informal knowledge. Informal knowledge networks in agriculture are "fuzzier" relations between community members, family and personal relations that occur as part of a farmers' daily routine (Šūmane et al. 2018, 237). Across these definitions, organizations are considered formal, while exchanges with personal relations are considered informal.

Yet, neither capture the characteristics of formalized peer-to-peer farmer networks, emerging as a unique entity that blends the benefits of the decentralized exchange of farmer knowledge within a structured organization. We briefly examined farmer organizations and associations in the US and found formal farmer-to-farmer networks to be a particular type, with the following shared characteristics: 1) a defined membership and organizational structure 2) leadership (e.g., board of directors) that includes farmers and 3) an emphasis on peer-to-peer learning. Of the organizations we examined, nine met these criteria including: GrassWorks, Iowa Organics Association (IOA), Nebraska Sustainable Agriculture Society, Northeast Organic Farming Association (NOFA), Ohio Ecological Food and Farming Association (OEFFA), PASA Sustainable Agriculture, Practical Farmers of Iowa, Southeastern African American Farmers' Organic Network (SAAFON), Sustainable Farming Association of Minnesota, and most producer-led watershed protection groups.

Across all formal farmer networks we examined, membership is state or regionally based and representative of various farming enterprises. Some of the networks (IOA, NOFA, OEFFA, SAAFON), have current or historic ties to organic-specific production. All of the networks have been established for over thirty years with the exception of IOA and SAAFON, both founded in 2006. The longest standing organization is NOFA (1971), followed by OEFFA (1979), and PFI (1985). PFI has the most robust programming offered to members; however, all formal networks offer some combination of programming and resources that include annual conferences; field days; written educational resources; mentorship or apprenticeship opportunities; email listservs; and/or classifieds to find or sell equipment, livestock, or post positions. Formal networks take on varying degrees of policy advocacy. Some organizations are proactive in farm policy, such as IOA or OEFFA, and others remain apolitical, such as Grassworks. While PFI advocates for policies promoting conservation practices, other core areas of programming such as farmer-to-farmer learning events, cost-share, and on-farm research receive priority over direct policy work.

While farmer cooperatives often result in the sharing of information and comradery inherent in networks, we do not consider them to be formal farmer networks as we define them, since cooperatives' objectives are largely economic — e.g., to improve bargaining power (Schram 2010) — as opposed to social. While we attempt to characterize formal farmer-to-farmer networks, we recognize that networks are diverse and suited to the needs and resources of the community the network serves (White 2021).

Formal farmer networks are particularly important in the transition to sustainable agriculture because of their role in bridging two valuable forms of knowledge: farmers' experiential knowledge shared between peers and formal scientific knowledge shared from professionally trained experts. Before the onset of public agricultural science, new knowledge was created through the cumulative experience of farmers and exchanged among themselves. This local knowledge has been largely devalued by the scientific community and loose networks of farmers sharing information have traditionally operated separately from agricultural extension (Kloppenburg 1991; Hassanein 1999; Kroma 2006). Agricultural extension primarily uses a top-down approach to disseminating scientific information from traditional "experts" to farmers (Warner 2007; Lubell et al. 2014). Criticisms of traditional agricultural extension have led to alternative research and extension models that involve the participation of farmers and other stakeholders (Chiffoleau and Desclaux 2006; Warner 2007; Healy and Dawson 2019) and the use of existing grower networks to extend agricultural science (Hoffman et al. 2015).

Still, these methods place the scientist and the extension professional at the center of the production of and dissemination of knowledge in agriculture, while research indicates that farmers are more likely to test or adopt innovations when information about the innovation is transmitted through peers (Rogers 2003). Formal famer networks are a promising collaborative way to produce and share both scientific and farmer knowledge because they privilege farmers' knowledge and learning in the process of dissemination.

In formal farmer networks, membership fees, grants, and/or donations help support network programming. Leadership facilitates the sharing of information by linking farmers with each other and by linking farmers with outside actors and institutions. Farmers connect through newsletters, email discussion lists and social media, and through social learning activities such as on-farm research trials and field days. In many of these formats, farmers are in the teaching role and farmer-generated knowledge is shared between participants. Leadership ties in university researchers and extension staff, conservation professionals, and other agriculture specialists to the network through events such as webinars and workshops, often conducted alongside farmer presenters. Network leadership may provide technical assistance, navigate cost share opportunities, work with farmers to trial new practices, analyze data from field trials, produce reports, and distribute informational material members can access independently. The result is a diversity of both sources of expertise and ways of learning within the network that includes farmer and "expert" generated knowledge, and in-person and independent learning pathways.

Using Rogers' (2003) explanation of diffusion, formal networks can be considered a hybrid of centralized and decentralized information exchange. In a centralized diffusion system, the decision to begin to diffuse an innovation is made by formal experts and spread downwards. In a decentralized system, information, often developed from practical experience, is spread horizontally among potential adopters. Formal farmer networks form a synergy between the benefits of peer exchange and access to information produced in institutions that may be missing from informal peer networks. With ties to both institutional actors and a network of farmers, formal farmer networks bridge social and institutional knowledge, playing a "boundary spanning" role (Levy and Lubell 2018).

In addition to experts sharing information with farmers, and farmers sharing information with each other, formal farmer networks provide opportunities for farmers to share feedback and information to experts, completing a feedback loop. In some formal farmer networks, farmers share their knowledge with agricultural researchers and provide feedback to agricultural scientists and extension agents on the performance of different conservation and production practices at events, on email discussion lists, and through the dissemination of research reports. Farmers also provide feedback to network leadership which drives programming decisions and signals to how to better assist members.

Despite the unique attributes of formal farming networks, few studies have quantitatively examined the role of participation in a formally organized peer-to-peer network in the adoption of conservation practices in the US. Within the body of literature predicting the adoption of best management or conservation practices, some studies include the degree of participation in community organizations (Belknap and Saupe 1988) and in agricultural or conservation organizations broadly (Korsching et al. 1983; Bates and Arbuckle 2017), which are found to be positively associated with adoption. Others examine the degree of farmer-to-farmer networking (Wilson et al. 2014), perceived effectiveness of learning from others including neighbors (Dunn et al. 2016), and importance placed on neighbors as an information source (Thomas et al. 1990), with varying results.

The two studies that consider a form of formal peer networks in quantitative studies of adoption are by Barbercheck et al. (2014) and Pape and Prokopy (2017). Barbercheck et al. (2014) looked at participation in various agricultural organizations among female farmers in the Northeastern US and the use of conservation practices. They found participation in an organized women's farming network to be positively associated with the adoption of one of 11 measured cropping system conservation practices—manure incorporation after application (Barbercheck et al. 2014). Pape and Prokopy (2017) found that farmers in two formal networks—defined as structured organizations with defined roles and purposes—in Indiana use a range of conservation practices more than non-network farmers, most of the differences significant at the 0.1% level. They also found a positive and significant relationship between the length of time a farmer participated in a network and self-reported improvements to their nutrient management practices (Pape and Prokopy 2017). Our research adds to the limited body of evaluative evidence of the role of farmer networks in the US in two key ways: 1) we focus on formally organized farmer networks, complementing existing ethnographic research on their role in farmer decision making and 2) we measure the intensity of participation for a more nuanced understanding of the role of the network.

3. Study context

We studied farmers within one longstanding formal farming network in the Midwest, Practical Farmers of Iowa (PFI), to understand how participation in the network relates to the adoption of conservation practices. PFI uses "farmer-led investigation and information sharing to help farmers practice an agriculture that benefits both the land and people" (PFI 2022a). The group has a history in the region of facilitating open dialogue between farmers to develop solutions to make farming more sustainable (Bell 2004). Established in 1985, a time when farmers were under great economic pressure, PFI was formed by a group of like-minded farmers who came together to increase diversity on their farms while also reducing input costs. Members learned from one another and organized to conduct randomized, replicated on-farm research to improve their profitability, efficiency, and stewardship (PFI 2022a). PFI has grown to an organization with over 6,000 members and 30 staff with program areas that extend beyond the initial row crop and livestock enterprises to include horticulture, beginning farmers, habitat restoration, and policy. From the summer of 2019 to the spring of 2020, PFI's events and workshops had 2,750 total attendees (personal communication with PFI Membership Manager, July 2021). Its members are primarily located in Iowa but include members across the country and internationally.

PFI member farmers, including both row crop and other types of member farmers, are different from the broader farming population in the region in that, on average, they are younger, have larger farms, and have lower rates of land ownership (USDA NASS 2017; PFI 2020). Member farmers have greater-than-average adoption of conservation practices compared to other farmers in the region. For example, only 11% of farmers across the Corn Belt reported using cover crops according to the most recent USDA agricultural census (USDA NASS 2017). Yet, in 2020, 67% of all PFI member farmers report using cover crops (PFI 2020). Similarly, PFI farmers report a higher use of reduced or no-till practices and enrollment in government conservation programs compared to the larger farming population in the region (USDA NASS 2017; PFI 2020).

4. Research questions and hypotheses

Using data from the three most recent PFI member surveys in 2013, 2017, and 2020, and interviews with member farmers, we ask the following questions: 1) What is the role of the PFI farming network in the adoption of conservation practices amongst its members? 2) What drives successful participation in the network? and, 3) Do the various ways member farmers participate and learn within the network matter for the adoption of conservation practices?

Knowing that the frequency and depth to which an individual interacts with a network increases the likelihood of the diffusion of information among participants (Cheng 2021), we measure participation for our first question by the degree of involvement in PFI events and workshops and engagement with PFI materials. The second question measures successful participation in the network by whether a farmer reported adopting a conservation practice as a result of participation in PFI. For our third question, we test whether in-person ways of participating traditionally associated with social learning in agriculture such as field days, socials, and workshops have a stronger relationship with adoption compared to independent ways of participation within the network more unique to formal farmer networks such as email discussion lists, participatory research reports, webinars, and podcasts.

Given the unique attributes of formal farmer networks to produce and share both scientific and farmer knowledge, and to provide opportunities for both social and independent learning, we hypothesize that participation in the network will be positively associated with the adoption of conservation practices. We theorize that engaging in a formal farmer network provides impactful opportunities to learn about conservation practices from other farmers and agricultural professionals while receiving support and validation, thereby increasing the likelihood one will adopt.

We also hypothesize that in-person and independent ways of engaging in the network do not have the same relationship with adoption. PFI offers a range of in-person events and ways of engaging remotely and accessing materials independently. The learning pathways a farmer can access independently within the PFI network can still be considered a blend of social and independent learning since they are created by or use data or information from other farmers. Nonetheless, we make a distinction between in-person participation and independent participation, hypothesizing that face-to-face interactions are more important for adoption than independent ways of learning and engaging within the network.

Existing theory of social learning and the diffusion of innovation holds that face-to-face, interpersonal channels of communication are more likely to influence an individual's decision making compared to impersonal sources due to the ability to observe and ask questions about practices (Bandura 1977; Ban 1981; Rogers 2003). This type of learning is especially important for conservation practices that tend to be more complex and knowledge-intensive compared to conventional practices (Carlisle et al. 2019; Laforge and Levkoe 2021). Moreover, empirical literature in agriculture shows that farmers place more value on social learning compared to institutional or top-down learning (Hoffman et al. 2015; Laforge and McLachlan 2018) and that social learning (Garbach and Morgan 2017; Singh et al. 2018), and particularly face-to-face ways of receiving information (Bates and Arbuckle 2017), have been shown to be a strong predictor of the adoption of conservation practices.

Results from this study can provide insights to other organized farmer networks in the region, inform the programming and allocation of resources amongst agriculture professionals and policy makers, and inform academics and extension professionals of the role of organized networks among the many factors determining whether a farmer chooses to use a conservation practice.

5. Methods and data

Farmer survey

The quantitative analysis used data collected by PFI in 2013, 2017, and 2020 through their member survey, a survey distributed to all members every three to four years. Access to this data was given to the researchers by the staff of PFI, with identifying information removed. The member surveys were disseminated via email and collected information about members' farms, farming practices, goals, feedback about past PFI programming, and future priorities for PFI. Members were encouraged to complete the survey through an online form, but were also given the option to complete a paper copy. The 2020 survey was disseminated in December of 2019 and responses were collected until March, 2020; the 2017 survey was disseminated February of 2017 and responses collected until July; and the 2013 survey was disseminated in September of 2013 and responses were collected until January of 2014. Over the course of each campaign, members were sent between one to four email reminders and staff posted general reminders in the e-newsletter and on the email discussion list. Incentives were offered to take the survey in the form of drawings for PFI promotional materials.

In 2020, 785 of 1,941 member households responded for a response rate of 40%, in 2017, 650 of 1,431 member households responded for a response rate of 45%; and in 2013, 660 of 1,286 member households responded for a response rate of 51%. Ninety-five percent of surveys in 2020 were collected before the onset of the Covid-19 pandemic as of March 11, 2020. Thus, the 2020 survey does not likely reflect changes in participation due to the pandemic. Cross sectional data from the three different survey periods were pooled and the most recent survey was used for individuals that completed the survey multiple years.

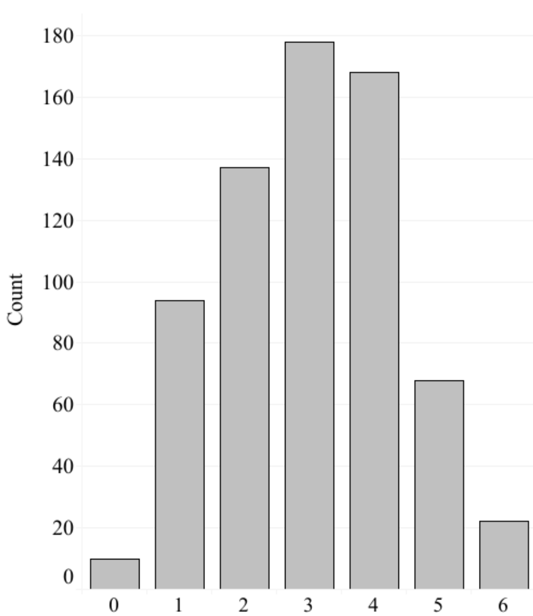
Only members who reported that they were currently farming were included in the analysis. We did not include other types of PFI members, such as farmland owners who do not operate their land, aspiring farmers, or friends of farmers. Farmers cultivating corn and/or soybeans, among other crops, are the largest membership contingency within PFI and constitute 53% of the farmers who responded to the membership survey. The other 47% of respondents cultivated a range of vegetables, fruits, flowers, hay, and livestock. We excluded farmers who had only been a PFI member for one year or less at the time of the survey, since we assume that it was less likely that PFI would have been the driver of their use of conservation practices. We judge a time lag of one year or greater to be a sufficient amount of time to adopt the majority of the practices measured.

After exclusions, the final sample size of the pooled cross-sectional data was 677 member farmers including 118 farmers in 2013, 149 in 2017, and 410 in 2020. The network attracts members throughout the US, although most live in Iowa and surrounding Corn Belt states. After exclusions, the states represented by farmers in the sample include Alabama (1), Arizona (1), California (1), Colorado (1), Iowa (590), Illinois (15), Indiana (1), Kansas (2), Kentucky (1), Michigan (1), Minnesota (23), Missouri (4), Montana (1), Nebraska (11), New Jersey (1), Ohio (6), Ontario Canada (1), Pennsylvania (1), South Dakota (5), and Wisconsin (10). Given that the vast majority of farmers in the sample reside in Corn Belt states, Iowa in particular, we use this region to compare our sample.

Regression variables

The first dependent variable, the *adoption of conservation practices index*, is a composite index ranging from 0 to 6 based on the sum of farmer-indicated use of the following practices (each are binary variables coded as yes=1 and no=0): buffer or filter strips (riparian, grass, prairie), conservation tillage (no till, strip-till, ridge-till, or reduced till), cover crops, flame or electric weeding, low-use of synthetic inputs (organic farming or no use of synthetic inputs), and sustainable grazing (rotational grazing or high-density/adaptive multi-paddock grazing). A score of 6 indicates use of all conservation practices listed and a score of 0 indicates no use of the practices listed. The distribution of the *adoption of conservation practices* index is displayed in **Figure 1.1**.

Figure 1.1 Distribution of the dependent variable *adoption of conservation practices index* using the pooled member survey data from 2013, 2017, 2020 (*n*=677)



These practices were derived from the member survey and are key practices elevated by PFI, clearly improving of conservation on farms, and applicable to all farms in the sample. While conservation practices have different levels of environmental and agronomic benefit (Reimer et al. 2014), we do not weight each practice within the adoption index. A lack of comparable data on the relative environmental impact across each practice, and the varying impact depending upon the biophysical conditions of each farm which are spread across a heterogenous geographical area, would make it difficult to do so. While some studies have attempted to differentially weight certain practices (Napier and Tucker 2001; Napier and Bridges 2002), other studies have used composite indexes similar to ours when analyzing adoption of best management practices in agriculture (Thomas et al. 1990; Park and Lohr 2005; Filson et al. 2009; Campbell et al. 2011).

The independent variable *general participation index* measures a farmer's participation in a range of events and resources offered through the network. We created an index according to the number of events attended and engagement with resources reported by the farmer completed in the past 12 months. In addition, we test the association of ways of participating and learning in the network and the adoption of conservation practices. We do so by defining two types of participating and learning—in-person and independent. In-person ways involve face-to-face social learning and independent ways allow the farmer to learn on their own through PFI materials.

Table 1.1 Main independent variable composition

Included Variables	**General participation index (0-7)**	**In-person participation index (0-4)**	**Independent participation Index (0-3)**	**Survey question**
Attended 1-2 events	Y	Y		The following are
Attended 3 or more events	Y	Y		events and resources

Acted as a farmer-leader (doubly weighted)	Y	Y		offered through PFI. Please select any you
Visited the PFI website	Y		Y	have done in the past
Read the PFI weekly e-newsletter	Y		Y	12 months.
Used the PFI e-mail discussion list	Y		Y	

We disaggregated the *general participation index* into two discrete indexes of in-person and independent ways of participation (Table 1.1). The *in-person participation index* includes the following categories: attended 1-2 events, attended 3 or more events, and acted as a farmer-leader. Acting as a farmer leader includes at least one of the following: conducted on-farm research, hosted a field day, talked to the media, served on a committee, or served as a mentor. This category is weighted doubly to account for greater integration into the network. The *independent participation index* includes: visited the PFI website, read the PFI weekly e-newsletter, and used the PFI e-mail discussion list. Each category that was checked is given a 1 (except for farmer-leader, which is weighted doubly as noted above) and summed for a final score, ranging from 0-7 for the combined index, 0-4 for the in-person index, and 0-3 for the independent index.

Each model includes additional covariates also shown to be associated with adoption in review studies (Baumgart-Getz et al. 2012; Carlisle 2016; Prokopy et al. 2019) and narrowed their inclusion to the best model fit according to those that increased the R^2 value. Of the predictor variables gleaned from the member survey, *age of primary member* farmer, total *farm size* in acres, *participation in EQIP* (Environmental Quality Incentives Program), *participation in a watershed group*, *proportion of acres owned*, and *years in PFI*, were included in the model.

Age of primary member is the age of the person who completed the survey. *Farm size* is the combination of acres owned and rented that are operated by the member farmer. *Participation in EQIP* measures present or past participation in EQIP. *Participation in a watershed group* measures current or past involvement in a watershed project. Watershed projects are farmer-led, governmentally funded cost-share programs with the aim of improving water quality through the use of conservation practices. *Proportion of acres owned* measures the proportion of acres owned and operated to total acres operated (rented and owned) and ranges from 0-1. The number of years of membership in PFI (*years in PFI*) was included to control for increased adoption due to length of time in the network and to isolate the association of increased participation and the adoption of conservation practices. A dummy variable for year in which the survey was distributed was included as a fixed effect to control for variation across years such as fluctuations in government conservation program supports, commodity prices, and weather which may have impacted adoption. The state in which the farmer is located (*state*) was included to control for distance to in-person events, as over 95% of PFI events are held in the state of Iowa (personal communication with PFI Membership Manager, July 13, 2021). Including state fixed effects also help to control for time-invariant environmental characteristics at the state-level that may influence the adoption of conservation practices such as climate and soil type.

The second dependent variable is *adopted a conservation practice(s) as a result of participation in PFI*[3]. We selected independent variables available through survey data to predict whether a farmer adopted conservation practice(s) as a result of participation in PFI, including *age of primary member*, whether the farmer reported having formed relationships through the network (*formed relationships*), whether the farmer reported having felt a sense of community through the network (*felt a sense of community)*, *years in PFI, state*, and year fixed effects.

Regression analysis

[3]In 2020 and 2017 the survey question read: "Have you changed any of the following as a result of your participation with PFI: conservation practices (reduce inputs, diversifying rotations, cover crops etc." In 2013 the survey question read: "My participation with PFI helped me improve stewardship on my farm" and noted "Stewardship can be anything you do to leave your farm in better shape for future generations, such as improvements that affect energy use, soil, water, and biodiversity or field conservation." While the questions are different, we believe that the intent is similar enough to be pooled in one variable for analysis.

Using R statistical software (Version 4.2.1), we created a series of regression models to understand the relationships between the *adoption of conservation practices index* and the three key independent variables described in Table 1: general, in-person, and independent participation in PFI. The three main independent variables were included in separate models due to theoretical and observed issues of multicollinearity. For general participation, we ran bivariate regressions between the *adoption of conservation practices index* and the *general participation index*, a multivariate regression with covariates and fixed effects, and a multivariate regression with covariates and fixed effects including an interaction between the *general participation index* and the number of *years in PFI*. The interaction was chosen due to the likelihood that general participation in PFI had a different relationship with adoption depending on the number of years the member had participated in the network. For in-person and independent modes of participation, we ran multivariate regressions with covariates and fixed effects. In addition, we ran a multivariate regression to understand the factors that predict whether a farmer adopted conservation practice(s) as a result of participation in PFI. We standardized the independent variables in all models to compare the relative importance of each while holding all other variables in each model constant.

We estimated the association with the *adoption of conservation practices index* and the independent variables in the model using two model types: a Generalized Linear Model (GLM) based on the binomial probability distribution and an ordered logistic model. The binomial GLM model best fits data with a dependent variable that is a discrete count composed of positive integers with an upper bound (McCullagh 2019). Unlike other count models, the binomial GLM model predicts the sum of the number of "successes" of a practice being adopted out of a set number of independent "trials" and will therefore not predict values outside the range of the adoption index. Because this data may have minor violations of independence of trials from the same individual, we conducted an ordered logistic regression to test the robustness of the binomial GLM results. For the ordinal logistic regression, we treated the dependent variable, *adoption of conservation practices index,* as ordered and discrete, allowing for the distances between intervals in the dependent variable to vary (Pampel 2021). A binary logistic regression model is used to predict the factors associated with the variable *adopted conservation practice(s) as a result of participation in PFI,* appropriate for models with a binary dependent variable.

Results for each model are expressed as the likelihood of being in a higher level of adoption with a unit increase in each independent variable (Models 1-6 and 8-11), or the likelihood of having adopted conservation practice(s) as a result of participation in PFI (Model 7) controlling for all other independent variables. We calculated a McFadden's pseudo R^2 to measure the predictive power of each model, an appropriate measure for the generalized linear, ordered logistic, and binary logistic regression with no R^2 value. To verify that our models did not violate assumptions and to improve confidence in our model selection, we performed a series of examinations for each model type. A study of correlation coefficients showed no signs of multicollinearity among the independent variables in any of the models. Residual versus fitted scatter plots indicated that the relationships between the independent and dependent variables were linear and the variance of the error terms constant. For the ordinal logistic regressions, a test of parallel lines (Brant 1990) showed no indication of a varied effect of the independent variables across levels of the adoption index, except for the variables farm size and year=2013. Given that proportional odds held for the key independent variables across the fitted models, we believe that the dependent variables are more appropriately treated as ordinal compared to nominal. No evidence of lack of model fit was found using a Wald Chi-squared test across all models, nor for the ordinal logistic models using a Lipsitz, Hosmer-Lemeshow and Pulkstenis-Robinson tests (Fagerland and Hosmer 2016).

In-depth interviews

In-depth, semi-structured interviews with a subset of the 410 farmers that filled out a member survey in 2019-2020 took place from July to December of 2020. We sampled farmers from the member survey using a stratified, maximum variation sampling technique (Patton 2002) to understand perspectives from a variety of member farmers. First, we limited the sample to those growing corn and or soybeans to focus on the group of farmers with the greatest environmental impact on the Midwestern landscape and representative of a majority of PFI's membership. Next, we divided surveyed farmers into four groups based on two axes, 1) their score on the adoption of conservation practices index and 2) their score on the general participation index, and randomly sampled within each of these four groups. Finally, after finding our sample to be composed of primarily men, we recruited and interviewed two additional women farmers through snowball sampling. Thirty-five farmers were contacted to participate in an interview; 71% agreed and were interviewed. In total, we interviewed 22[4] current members and 4 previous member farmers who had not renewed their membership. The farmers we interviewed represent 1.3% of member households in the PFI network.

Farmers were told in the beginning of the interview that PFI was financially supporting the study, but that the interviewers were independent and no information from the interviews would be published or relayed back to PFI staff without all individual identifying information removed. Interviews were conducted via Zoom or in person depending on location and farmer preference, and lasted between 45 to 90 minutes. Questions focused on the factors that allowed them to transition to conservation practices, preferred learning and information sources, and experience with

[4] Two farmers were interviewed together, and their responses are counted as one in the findings because they took turns answering questions.

and opinions on the PFI network[5]. Interview data were analyzed using NVivo software and coded according to an inductive approach that identified reoccurring themes.

6. Results

PFI and the adoption of conservation practices

Regression results

The dependent variable, *adoption of conservation practices index*, is displayed disaggregated by practice and by the extent of participation in the PFI network in **Figure 1.2**. Each practice that was included in the index is displayed by the proportion of member farmers that reported use. Low use of synthetic inputs and use of cover crops had the highest adoption among PFI farmers, at 75% and 61%, respectively. To understand how the adoption of each practice varied by the extent of participation in the network, we divided farmers into two groups, high and low participators, where high (*n*=292) participators engaged in 4-7 of the activities listed and low participators (*n*=385) engaged in 0-3. For all conservation practices, high participators are also those with higher rates of adoption, on average (**Figure 1.2**).

Figure 1.2 Dependent variable *adoption of conservation practices index* disaggregated by practice and by proportion that selected yes using the pooled member survey data from 2013, 2017, 2020 (*n*=677) and further disaggregated by level of participation in PFI (High: *n*=292; Low: *n*=385)

[5] Interview protocol is available on request from the corresponding author.

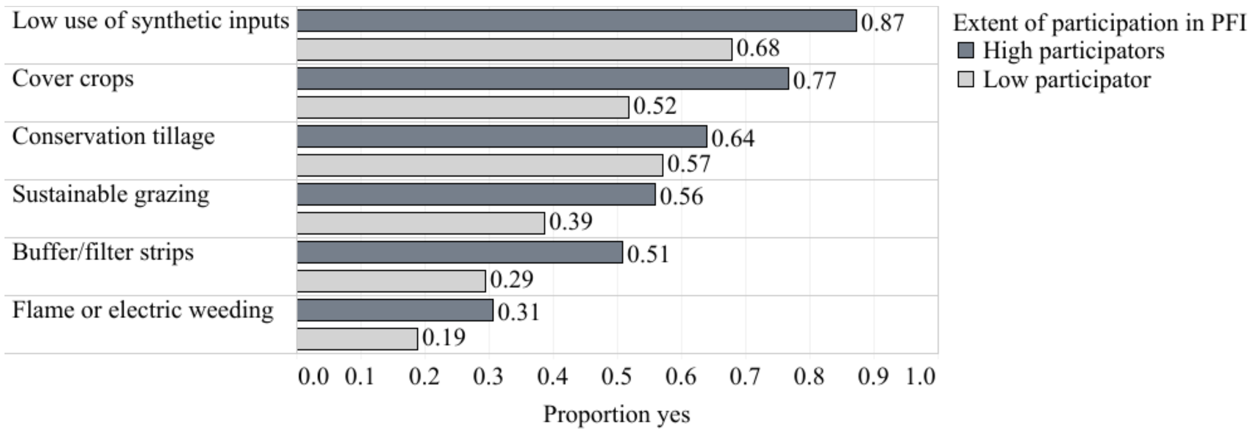


Figure 1.3 shows our main independent variable, *general participation index*, disaggregated by each type of activity or resource and by level of adoption of conservation practices. The most common way PFI member farmers participated in the network was through the PFI website. Over 80% of farmers said that they visited the website in the past 12 months. The PFI website includes resources organized by program area, PFI publications including the quarterly magazine, annual report, the Cooperators' Program on-farm research reports, a member portal, and information about upcoming events. Farmers also frequently reported reading the PFI weekly e-newsletter (75%), attending 1-2 events per year (66%), and using the PFI email discussion list (53%). The newsletter shares information about upcoming events, member and organizational achievements or features in the media, publications, announcements, and highlights of timely resources. PFI offers in-person events including field days, conferences, workshops, regional meet-ups, socials, multi-day bus trips, and mentorship opportunities. Discussion lists are used by members and staff to ask and answer questions, post items for sale or needed, send announcements, and disseminate information on other resources and events outside of PFI. Specific lists exist concerning general announcements, field crops, livestock, and horticulture, and a perspectives list that provides space for members to engage in open-minded debate and discussion related to agriculture (PFI 2022b). Fewer farmers

attended 3 or more events per year, or served as a farmer leader (i.e., conducted on-farm research, hosted a field day, talked to the media, served on a committee, or served as a mentor). **Figure 1.3** also displays participation in the network by level of adoption of conservation practices where high adopters (*n*=258) used between 4-6 conservation practices and low adopters (*n*=419) used between 0-3. High adopters participated slightly more in each avenue listed besides attending 3 or more events, which was almost equal across adopter groups.

Figure 1.3 Main independent variable *general participation index* disaggregated by activity/resource and by proportion that selected yes using the pooled member survey data from 2013, 2017, 2020 (n=677) and further disaggregated by level of adoption of conservation practices (High: *n*=258; Low *n*=419)

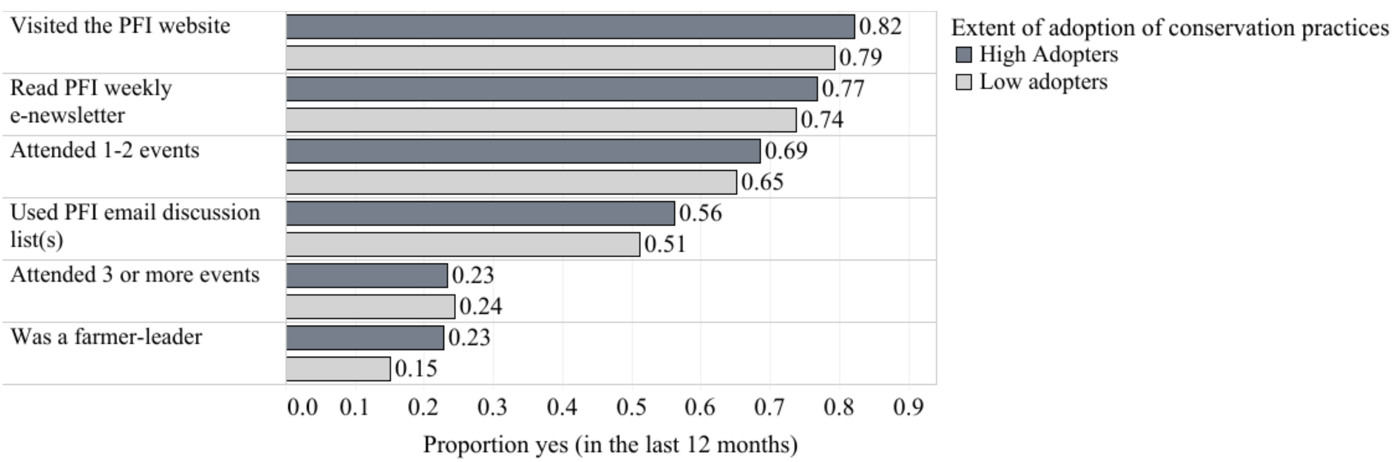


Table 1.2 summarizes the results of the regressions measuring the relationship between the *adoption of conservation practices index* and the *general participation index*. The results show that farmers' level of participation in PFI is statistically significant in explaining the level of adoption of conservation practices. The higher a farmer's level of participation in PFI, the more likely it is that they will have a higher level of adoption of conservation practices, on average. Results are robust across both the bivariate and multivariate GLM binomial (Models 1 & 2) and ordinal logistic (Models 4 & 5) models. General participation in PFI has the second most statistically significant

relationship with adoption, following participation in EQIP, across all covariates (excluding Year 2013 fixed effects) included in the GLM binomial Model 2 (*p*= 0.0001) and ordinal logistic Model 4 (p=0.0003). These findings support existing scholarship showing that the degree of participation in conservation organizations (Korsching et al. 1983; Belknap and Saupe 1988; Bates and Arbuckle 2017) and the degree integration into or centrality within social networks broadly (Phelps et al. 2012; Cheng 2021) drive the diffusion of technology.

Table 1.2 GLM binomial and ordinal logistic regression models predicting adoption of conservation practices using the pooled member survey data from 2013, 2017, 2020

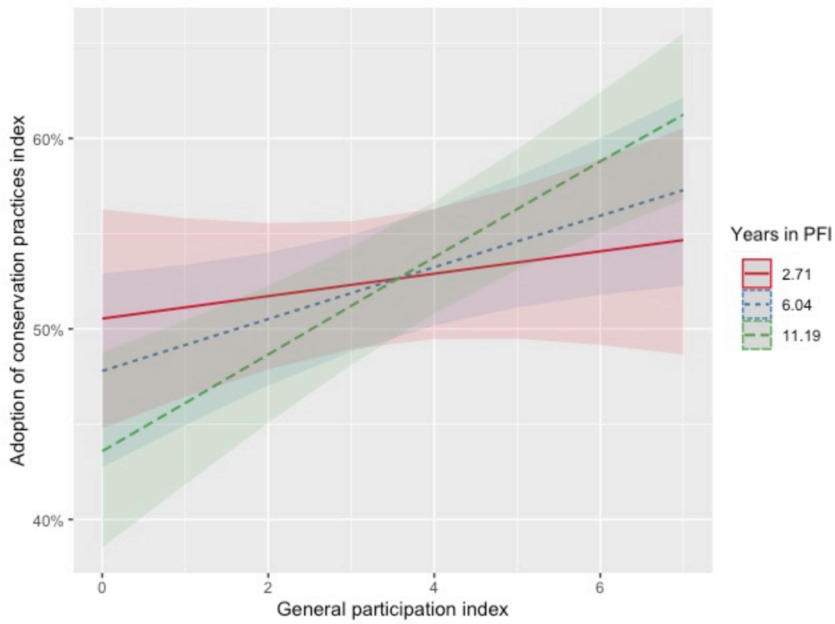
	Dependent variable:					
	Adoption of conservation practices index					
	GLM logistic				*ordered logistic*	
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
General participation index	**0.121*****	**0.148*****	**0.123*****	**0.220*****	**0.298*****	**0.251*****
	(0.032)	(0.038)	(0.039)	(0.068)	(0.081)	(0.083)
	p = 0.0002	p = 0.0001	p = 0.002	p = 0.002	p = 0.0003	p = 0.003
Age of primary member		0.015	0.007		0.011	-0.007
		(0.042)	(0.043)		(0.092)	(0.092)
		p = 0.731	p = 0.873		p = 0.904	p = 0.942
Farm size		**0.087****	**0.084****		**0.150***	0.146
		(0.042)	(0.042)		(0.091)	(0.092)
		p = 0.038	p = 0.047		p = 0.098	p = 0.111
Participation in EQIP (yes=1)		**0.166*****	**0.170*****		**0.354*****	**0.359*****
		(0.039)	(0.039)		(0.084)	(0.085)
		p = 0.00002	p = 0.00002		p = 0.00003	p = 0.00003
Participation in a watershed project (yes=1)		0.055	0.045		0.109	0.094
		(0.036)	(0.037)		(0.075)	(0.076)
		p = 0.129	p = 0.218		p = 0.149	p = 0.217
Proportion of acres owned		**-0.120*****	**-0.114*****		**-0.246*****	**-0.238*****
		(0.040)	(0.040)		(0.087)	(0.087)

		p = 0.003	p = 0.005		p = 0.005	p = 0.007
Years in PFI		-0.001	-0.015		0.012	-0.011
		(0.040)	(0.041)		(0.086)	(0.087)
		p = 0.981	p = 0.709		p = 0.893	p = 0.901
State		0.073**	0.070**		0.170**	0.162**
		(0.035)	(0.035)		(0.074)	(0.074)
		p = 0.034	p = 0.043		p = 0.022	p = 0.029
Year 2017		0.001	0.009		0.005	0.021
		(0.042)	(0.042)		(0.091)	(0.092)
		p = 0.986	p = 0.832		p = 0.961	p = 0.818
Year 2013		**0.199*** **	**0.195*** **		**0.477*** **	**0.466*** **
		(0.038)	(0.038)		(0.085)	(0.085)
		p = 0.00000	p = 0.00000		p = 0.00000	p = 0.00000
Combined participation index* Years in PFI			**0.123*** **			**0.226*** **
			(0.036)			(0.075)
			p = 0.001			p = 0.003
Constant	0.015	**0.071***	0.056			
	(0.031)	(0.037)	(0.037)			
	p = 0.637	p = 0.056	p = 0.133			
Observations	677	516	516	677	516	516
Log Likelihood	-1,158.620	-835.720	-829.512			
Pseudo R^2 (McFadden's)	0.02	0.13	0.15	0.005	0.28	0.28
Akaike Inf. Crit.	2,321.24	1,693.44	1,683.02	2,304.03	1,697.25	1,689.96
Wald Chi-squared	0.22	76.40***	82.90***	10.31**	80.56***	88.98***
Hosmer and Lemeshow test				*p*=0.95	*p*=0.73	*p*=0.59
Lipsitz test				*p*=0.58	*p*=0.90	*p*=0.49
Pulkstenis-Robinson test				*p*=0.62	*p*=0.58	*p*=0.79

Asterisks and bolding note statistical significance at or below the 10% level; * is <0.1; ** is <0.05, and *** is <0.01
Standard errors are listed in parentheses
Note: All coefficients have been standardized

While *years in PFI* is not significant in the multivariate Models 2 and 5, when interacted with the *general participation index*, the two combined have a strong effect on the *adoption of conservation practices index* (Model 3: p=0.001, Model 6: p=0.003). **Figure 1.4** visually displays the moderating role of the length of time in the network on the relationship between participation and the adoption of conservation practices. For farmers who have been in the network for 11 years (long dotted green line), the association between their participation in PFI and their adoption of conservation practices is the strongest, indicated by the steepest slope. For farmers who have spent less than three years in the network (solid red line), the association between their participation in PFI and their adoption of conservation practices is the weakest, shown by the flattest slope. Thus, the interaction term in Models 3 and 6 and the relationships displayed in **Figure 1.4** show that the effect of greater participation in the network is the strongest when a member has been in the network for a longer period of time. Some existing research points to the importance of length of time in a farmer network to the adoption of conservation practices; Pape and Prokopy (2017) found that the length of time spent in formal networks in Indiana was positively associated with the use of better nutrient management practices. However, ours is the first research to date that has examined the combined effects of length of time spent in a farmer network and the degree of participation on the adoption of conservation practices.

Figure 1.4 Interaction plot between the percentage of practices adopted within conservation practices index and the general participation index by the number of years in PFI (*n*=677). The colors represent varying levels of years in PFI.



Note: Years in PFI are shown in the lower, median, and upper quartiles. The width of the bands of each group of years in PFI represent the upper and lower values of the 95% confidence intervals.

Across the covariates, a farmers' *participation in EQIP* and *proportion of acres owned* are associated with adoption at the 1% level of significance in all multivariate models (Models 2-3 & 5-6). The association between participation in EQIP and higher adoption is in line with several review studies that find conservation program participation has an overall positive relationship with adoption of conservation practices (Knowler and Bradshaw 2007; Prokopy et al. 2008; Carlisle 2016). The more acres of their total operation a PFI member farmer owns, as opposed to rents, the less likely they are to adopt a greater number of conservation practices was a surprising finding given that existing theory points to the advantages of owning land for receiving the longer-term benefits of conservation practices (Belknap and Saupe 1988; Soule et al. 2000). However, renting more acres may allow farmers to expand their farm size and larger farms are shown to enable farmers to absorb risk and adopt more due to economies of scale (Khanna et al. 1999; Ulrich-Schad et al. 2017; Durant et al. 2023) which may explain why farm size is also significant at the 5% level in the GLM multivariate models (Models 2 & 3). Within the fixed effects, we note that 2013 is strongly associated with adoption compared to 2017 or 2020. In the years following 2013, there was a greater effort placed on membership recruitment and a broader group of both conservation and conventional-minded farmers joined PFI (personal communication with PFI Senior Programs and Member Engagement Director, November 2021). For this reason, it is likely that in 2013, adoption rates were higher due to the composition of the membership that tended towards higher adopters.

Knowing that participation in PFI is important for the adoption of conservation practices among members, it is useful to understand more precisely what drives successful participation in the network. **Table 1.3** shows the logistic regression model (Model 7) with the dependent variable *adopted conservation practice(s) as a result of PFI* and several independent variables from the survey data that might predict the change. We find that, on average, those who said they *formed relationships* through the network were the most likely to report *adopted conservation practice(s) as a result of PFI* in terms of significance (p<0.000), and coefficient size (1.789) holding all other variables in the model constant. This is in line with theories of social learning suggesting that farmers who are friends or in intentional relationships share more information, increasing the likelihood of adoption (Liverpool-Tasie and Winter-Nelson 2012; Mekonnen et al. 2022). Additionally, those who participated more (*general participation index*, p=0.014) and those who reported feeling a sense of community (*felt a sense of community through the network*, p=0.026) were also more likely to report adopting a conservation practice as a result of PFI. The *age of primary member*, the number of *years in PFI*, and the *state* in which they reside are not significant. Taken together, the independent variables in the model are strong predictors of whether a farmer adopted one or more conservation practices as a result of PFI indicated by a high pseudo R^2 (0.55).

Table 1.3 Logistic regression model predicting the change of conservation practices as a result of participation in PFI using the pooled member survey data from 2013, 2017, 2020

	Dependent variable:
	Adopted conservation practice(s) as a result of participation in PFI
	Model 7
General participation index	**0.491****
	(0.198)
	p = 0.014
Age of primary member	0.012
	(0.173)
	p = 0.945
Formed relationships (yes=1)	**1.789*****
	(0.150)
	p = 0.000
Felt a sense of community (yes=1)	**0.335****
	(0.150)
	p = 0.026
Years in PFI	0.179
	(0.191)
	p = 0.348
State	-0.085
	(0.146)
	p = 0.562
Year 2017	**-0.328****
	(0.147)
	p = 0.027
Year 2013	**-0.583***
	(0.314)
	p = 0.064
Constant	**1.386*****
	(0.202)
	p = 0.000
Observations	548
Log Likelihood	-145.904
Pseudo R^2 (McFadden's)	0.55
Akaike Inf. Crit.	309.808
Wald Chi-squared	47.30***

Asterisks and bolding note statistical significance at or below the 10% level; * is <0.1; ** is <0.05, and *** is <0.01

Standard errors are listed in parentheses
Note: All coefficients have been standardized

Farmer-reported results

Farmers reported their own experience with PFI and the use of conservation practices through the survey and through in-depth interviews. Using the pooled survey data from 2013, 2017, and 2020 we find that 71% of farmers said they adopted conservation practice(s) as a result of their participation in PFI (**Table 1.4**). Similar to the survey, when asked about the role of PFI in their transition to sustainable practices during in-depth interviews, 68% of farmers told us that their engagement in PFI helped. Farmers said that the PFI network provided information, resources, encouragement, and confidence building. Below we provide two illustrative examples from the 18 farmers who noted this. Farmer 2 explained:

> I feel like PFI has been a huge source of information and encouragement…Probably, because of PFI's opportunities for learning and information sharing, it has given us maybe confidence to try something we might've been thinking about.

Farmer 3 echoed the regression findings on the importance of the length of time spent in the network for the impact of participation to be fully realized, which they attribute to the ability to observe practices used successfully by other members over longer periods of time:

> I probably wouldn't have used cover crops quite as much if I hadn't seen PFI members doing it for a long period of time. That gave me confidence to try. Even though I probably philosophically knew it was the right thing to do, it was probably a little bit scary for me to do it at the beginning…seeing people do that… that were farmers, allows me to, not be quite as scary to try something like that.

Two other farmers noted that PFI helped to reinforce their decisions to adopt a new practice:

Farmer 16: I'm not sure I've changed a lot of practices with PFI…But they have solidified some things that, yes, I think I'm going down the right track. Or maybe I've learned something that's tweaked the practice a little bit.

Farmer 19: The role of PFI in my life was to reinforce the decisions that I was making. To feel validated, I guess, about the decisions that I was making…So, I was already headed down the road toward a more diversified production, longer rotations, soil conservation, protecting the quality of the water. Heading down that road. But PFI just kind of gave me the validation and reinforcement that I felt like I needed to keep doing that. Which is an important role. I mean, you know?

Table 1.4 Famer reported experience of the PFI network using the pooled member survey data from 2013, 2017, 2020

	Pct.	SD	*n*
Adopted conservation practices as result of participation in PFI (1=Yes)	71%	0.45	667
Formed relationships through the network (1=Yes)	73%	0.44	567
Felt a sense of community through the network (1=Yes)	78%	0.41	570

Farmers also reported on the social impacts of their participation in the member survey. Seventy-three percent of farmers that they formed friendships, business relationships, or relationships through the network and 78% percent reported feeling a sense of community through the network (**Table 1.4**). In an open-ended survey question about the impact of their PFI relationships, the most common responses included receiving new information and ideas, learning from the experience of others, and feeling social support from like-minded farmers. These farmer-reported impacts of network participation and the results of the regression in **Table 1.3** show that the personal relationships formed through the network, together with greater participation (as measured by the *general participation index*) and a widespread sense of community, are important to explaining successful participation in the network.

Ways of participating and learning in the network

Regression results

When considering ways of participating in the network separately, engagement through both in-person (Models 8 & 9) and independent (Models 10 & 11) pathways have a positive and significant relationship with increased adoption of conservation practices (**Table 1.5**). Thus, participating more, regardless of the format, is associated with greater adoption. However, in-person participation has a stronger relationship with adoption compared to independent participation in terms of statistical significance and the standardized coefficient size across both GLM binomial and ordinal logistic models. We use the McFadden's Pseudo R^2 and Akaike Information Criterion) (AIC) values to compare model fit across the in-person and independent participation models. The best model is signified by the highest Pseudo R^2 value and lowest AIC value. A difference of 2 between the AIC values is considered substantial (Burnham 2002). The in-person participation models (Models 8 & 9) have higher Pseudo R^2 values and AIC values are 10 units lower than the independent participation models (Models 10 & 11), indicating that in-person participation is significantly better than independent participation at predicting the level of adoption of conservation practices.

Table 1.5 GLM binomial and Ordinal logistic regression models comparing in-person and independent participation indices and the level of adoption of conservation practices using the pooled member survey data from 2013, 2017, 2020

	Dependent variable:			
	Adoption of conservation practices index			
	GLM logistic	*ordered*	*GLM logistic*	*ordered*

	Model (8)	*logistic* Model (9)	Model (10)	*logistic* Model (11)
In-person participation index	**0.124***** (0.032) p = 0.0001	**0.248***** (0.066) p = 0.0002		
Independent participation index			**0.087**** (0.041) p = 0.032	**0.176**** (0.088) p = 0.046
Age of primary member	0.005 (0.042) p = 0.911	-0.003 (0.091) p = 0.976	-0.001 (0.042) p = 0.981	-0.023 (0.091) p = 0.804
Farm size	**0.083**** (0.041) p = 0.045	0.143 (0.088) p = 0.104	**0.080*** (0.042) p = 0.056	0.136 (0.092) p = 0.137
Participation in EQIP (yes=1)	**0.168***** (0.038) p = 0.00002	**0.359***** (0.084) p = 0.00002	**0.177***** (0.038) p = 0.00001	**0.370***** (0.084) p = 0.00002
Participation in a watershed project (yes=1)	0.046 (0.036) p = 0.203	0.089 (0.075) p = 0.235	0.060 (0.037) p = 0.101	0.114 (0.076) p = 0.137
Proportion of acres owned	**-0.117***** (0.040) p = 0.004	**-0.242***** (0.087) p = 0.006	**-0.126***** (0.040) p = 0.002	**-0.252***** (0.087) p = 0.004
Years in PFI	0.007 (0.040) p = 0.859	0.025 (0.086) p = 0.773	0.015 (0.040) p = 0.712	0.038 (0.086) p = 0.662
State	**0.077**** (0.035) p = 0.027	**0.174**** (0.074) p = 0.019	**0.059*** (0.034) p = 0.087	**0.138*** (0.073) p = 0.058
Year 2017	0.008 (0.042) p = 0.849	0.020 (0.091) p = 0.830	-0.001 (0.042) p = 0.978	0.011 (0.091) p = 0.906
Year 2013	**0.201***** (0.038) p = 0.00000	**0.483***** (0.085) p = 0.00000	**0.182***** (0.037) p = 0.00000	**0.447***** (0.085) p = 0.00000

Constant	-0.085 (0.055) p = 0.127		-0.107 (0.093) p = 0.251	
Observations	516	516	516	516
Log Likelihood	-835.653		-841.043	
Pseudo R^2 (McFadden's)	0.13	0.28	0.11	0.27
Akaike Inf. Crit.	1,693.31	1,697.00	1,704.09	1,707.04
Wald Chi-squared	8.78***	81.10***	7.77***	70.80***
Hosmer and Lemeshow test		*p*=0.39		*p*=0.40
Lipsitz test		*p*=0.34		*p*=0.84
Pulkstenis-Robinson test		*p*=0.55		*p*=0.26

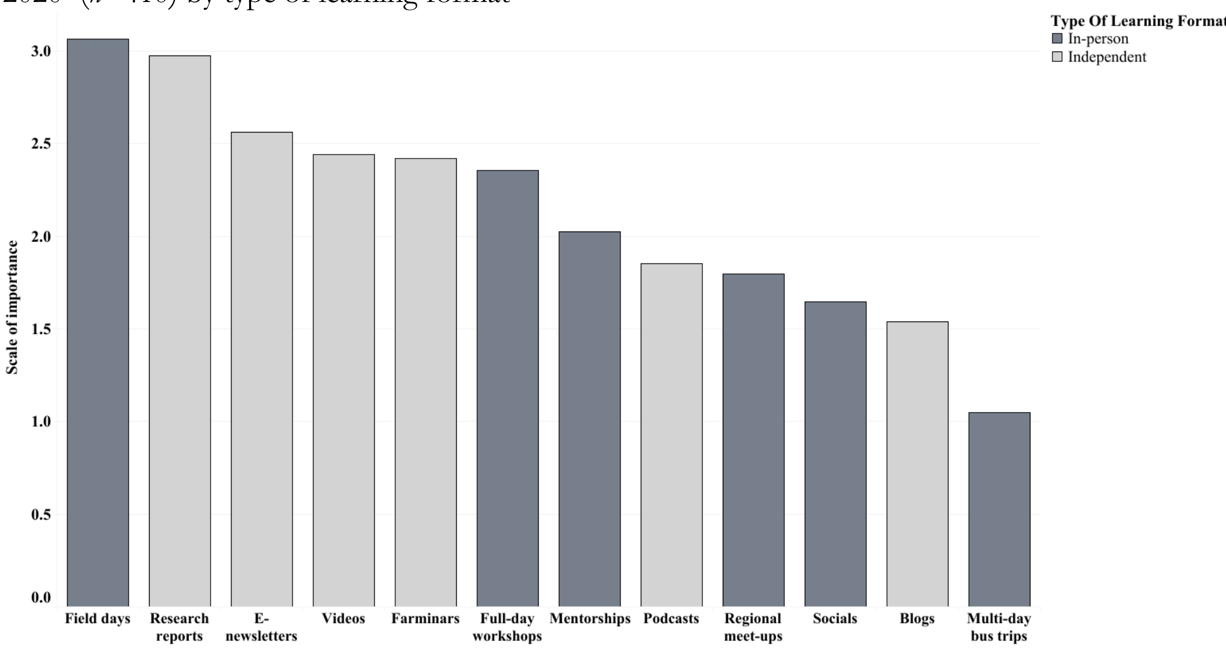
Asterisks and bolding note statistical significance at or below the 10% level; * is <0.1; ** is <0.05, and *** is <0.01
Standard errors are listed in parentheses
Note: All coefficients have been standardized

Other studies have reached similar conclusions regarding the greater effectiveness of social learning in agriculture compared to formal learning (Hoffman et al. 2015) and independent or institutional learning (Laforge and McLachlan 2018). Social learning has been shown to be a predictor of the adoption of conservation practices in the form of interaction with innovative neighbors (Garbach and Morgan 2017) and attendance at demonstration sites and field days (Singh et al. 2018). Our results mirror findings from Bates and Arbuckle (2017) who looked at farmer preferences for receiving information through face-to-face formats (field days, meetings, or workshops) and non-face-to-face formats (online videos or downloaded publications). The authors found that those who preferred to receive information about nutrient management through face-to-face formats reported using more diverse nitrogen management practices that help reduce nutrient loss (Bates and Arbuckle 2017).

Farmer-reported results

In terms of preferred ways of learning and participating in the network, farmers reported that they value a range of ways of engaging, including both in-person and independent formats[6]. In the 2020 member survey, farmers were asked to rate the importance of learning formats offered through the network. The most highly-ranked ways of participating were attending field days followed by reading research reports, reading E-newsletters, watching videos, participating in farminars, and participating in full-day workshops (**Figure 1.5**).

Figure 1.5 Average ranked importance of PFI learning formats using the member survey data from 2020[a] (*n*=410) by type of learning format



[a] Member survey data was not available for this question for the 2013 and 2017 surveys

To improve our confidence in the results of the in-person versus independent participation regressions (Models 8-11) and farmer-reported learning preferences in the member survey (**Figure**

[6] Figure 6 includes only 2020 member survey data. Data was not available for this question for the 2013 and 2017 surveys.

1.5), as well as to understand the reasoning behind why farmers prefer one learning format to another, we asked farmers about their learning and participation preferences during in-depth interviews. While farmers reported that they value a combination of in-person and independent learning formats in the survey, during in-depth interviews the majority (68%) of farmers told us that they preferred in-person formats. Farmers said that they use independent sources like research reports and videos for their ease of access, and to stay up to date and connected. However, several key themes emerged around the relatively greater importance of in-person formats that align with existing literature on the benefits of face-to-face interaction for social learning (Bandura 1977; Ban 1981; Rogers 2003): the ability to have side conversations, ask follow-up questions, and to observe results for themselves.

Side conversations: Eight of the farmers interviewed discussed the importance of being able to talk with and learn from other farmers during unstructured portions of network events, allowing them to ask follow-up questions and gain a more detailed understanding of the practice. Three illustrative quotes from the interviews are below:

> Farmer 5: …some of the things that I do miss since Covid is like, we would go to three, four, five field days in a summer, and the side conversations that we had were just as valuable as the content of the field day.
>
> Farmer 16: …where do you really learn something? It's the breaks or having a beer at the bar afterwards. That's where you really learn something, in my opinion. [Regarding reading a blog or research report,] I learn something, I learn a concept. But not the details.
>
> Farmer 21: Attending [the field day] live you get some of that community because you can ask questions…what often would happen is you might ask a question and the person who's

running the field day will answer it and then you end up having a discussion with the farmer next to you about their answer. You get two farmer's perspectives, not just one...

Seeing is believing: A core tenant of farmer-to-farmer learning, as emphasized by Rosset et al. (2011) is "seeing is believing," which highlights the importance of seeing results with one's own eyes for the successful diffusion of innovation. This sentiment was echoed by six PFI farmers when explaining the importance of in-person learning. Two of them described this succinctly as:

> Farmer 17: The physical presentation of the evidence and getting to see it is just always more impactful than reading about it in a textual format.
>
> Farmer 19: What helps the most is seeing other farmers adopt any new practices and that's where I think that PFI excels is in their field days and showing people how it can be done and making public what their neighbors are doing.

As interviews took place during the first year of the Covid-19 pandemic in the US (July-December 2020), we asked farmers whether their learning and participation preferences were changing due to the newly offered virtual and hybrid formats. Seven farmers expressed appreciation for the flexibility and accessibility of virtual options that they could view on their own time and forgo the travel time and cost, explained by two of them as:

> Farmer 2: (Remote field days are) not as good as being in person. But in reality, with taking on the cropping more this year, there is no way I could have taken time to actually drive to all the ones that I'd be interested in. And as much as I really liked doing it in person, the few field days I did attend virtually, it really just took literally the hour that it lasted or whatever. And I could go right back out and work again, and not take the time to drive and come back and whatnot.

Farmer 7: With the Covid this year it was kind of nice because there was a couple field days that I probably wouldn't have attended due to distance. But because they were on video, I watched them…I could watch it on my time versus when it was happening. I didn't have to take off of work. It kind of fit my schedule a little better.

One farmer noted the benefits of hybrid participation options that allow for live feedback and questions:

Farmer 15: I think after Covid I'm going to want to go to live events, I'm going to want to go and meet people face-to-face. But I really like the approachability of the Facebook Live in addition to face-to-face, both being held at the same time. I mean, we have the ability to do all that so it's nice to have options.

While nearly all farmers we interviewed appreciated having both in-person and remote options available to them, preferences for face-to-face interaction persisted during the early stages of the Covid-19 pandemic and 72% said that they planned to return to in-person participation when possible. This general sentiment was encompassed by one farmer as:

Farmer 18: I can't wait to be able to have the in-person stuff again because you still need that interaction with people that listserv and Farminars don't provide.

These quotes re-iterate the power of in-person learning and help explain the results of the regressions in **Table 1.5** that attest to the greater importance of in-person formats for the adoption of conservation practices. The benefits of and preference for in-person learning likely feeds into the sense of community and relationship building occurring through the network as reported by farmers in the member survey.

7. Discussion, limitations, and areas for future research

Because few farmer networks are as large and as long standing as PFI and even fewer collect systematic data from members, we use these unique data to gain greater insight into how the degree of participation in a network is associated with levels of adoption of conservation practices among network participants. We then add to and triangulate the survey data with our qualitative data from in-depth interviews with a subset of member farmers. Our findings support our hypothesis that greater engagement in the PFI network leads to greater use of conservation practices amongst member farmers. Quantitative results show a strong and positive association between participation in the PFI network and the use of conservation practices among members. These results are robust across GLM binomial and ordinal logistic models using pooled data from three years of member surveys. Qualitative interviews reinforce this finding: 76% of farmers told us that participation in the network helped them to transition to sustainable practices, or reinforced their decision to do so, by providing information, resources, encouragement, and confidence building. The effects of participation on adoption are enhanced by participating in the network for a longer period of time, as shown by the positive sign and significance of the interaction between the general participation index and the adoption of conservation practices index. Interviews with farmers suggest this could be due to feedback loops involved with seeing practices used by peer farmers successfully over longer periods of time. For farmers' participation in the network to be successful, measured as adopting one or more conservation practices as a result of participation, social ties within the network are important, particularly forming relationships. These results add to the literature quantifying the role of formal farmer networks in the adoption of conservation practices and add a nuanced analysis of the role of social networks by measuring the extent of engagement in one well known network in the Midwest.

This research also tests theories of social learning and diffusion of innovation that suggest that in-person, interpersonal channels of communication are a more effective means of changing an individual's behavior compared to information from impersonal sources. Findings from both our quantitative and qualitative data affirm existing theories of the relatively greater effectiveness of in-person learning, but also point to the complementary nature of the two modes. While PFI farmers appreciated a variety of both in-person and independent ways of engaging in the network, regression results show a stronger relationship between adoption and in-person participation compared to independent participation. In-depth interviews improved our confidence in these regression results by showing that more of the farmers we interviewed (68%) preferred in-person learning formats to support them in their transition to sustainable agriculture. Interviews suggest that this is because PFI farmers are more likely to adopt when they can observe other farmers using a practice, hear about other farmers' experiences, and ask questions through activities such as field days and workshops.

As researchers continue to search for quantitative models that explain the use of conservation practices in agriculture, our results show that involvement in a formal social network is an important variable for predictive models determining adoption. Our results also show that the type of participation matters, and that when farmers engage in person, they benefit from the direct interaction with peers these formats afford.

However, due to the cross-sectional research design of this study, which it shares with many studies in this literature, we cannot quantitatively prove a causal relationship between the degree of participation in PFI and the adoption of conservation practice because of two main limitations. First, those who join PFI may have certain characteristics that lead them to both participate in a sustainable farming group like PFI *and* to adopt conservation practices. As we saw from the differences between PFI farmers and the general farming population (see Study context), PFI farmers can be considered early adopters and motivated by deeply held values like altruism or other intrinsic motivations. We include covariates in our models that are shown to be associated with adoption in other studies, but due to the limitations of the survey data set, we cannot control for other potential confounding factors that may influence the intensity of both adoption and participation such as environmental ethic, labor availability, free time, and financial resources.

Second, farmers may have adopted a practice before joining PFI or greater adoption may be causing greater participation as opposed to the other way around. While we removed observations that had not been a PFI member for more than one year since taking the survey to ensure that adoption is measured at least one subsequent year since participating in the network, we do not have sufficient data on the same farmers over multiple years to compare each farmers' change in participation and adoption over time. Once a farmer adopts a conservation practice, the need for information may increase, which is possible given the more knowledge-intensive nature of conservation practices. In this case, adoption may be driving participation as farmers seek additional resources and support. Even if it is the case, this scenario, along with data from farmer interviews, still speaks to the importance of the network as a resource and one that may spur greater or sustained adoption.

Longitudinal studies tracking adoption of a set of farmers before and after network participation, or better yet, experimental studies that randomly facilitate membership in a network and measure any changes in adoption, can help to gain a more precise understanding of whether formal farmer networks are in fact driving the adoption of conservation practices. Still, the effects of network participation are nuanced, with impacts causal studies may not capture. Interview results show that in some cases PFI is a driver of adoption while in others it helps sustain adoption for those that have already started on this path. Both effects are important as the disadoption of conservation practices among farmers is common and can erase their accumulated environmental benefits (Sawadgo and Plastina, 2022).

Longitudinal and experimental studies, however, are often more costly, time consuming, and can ask more of already time-constrained farmers. This study uses existing data collected by PFI to contribute to the limited literature aimed at understanding the role of formal farmer-to-farmer networks. While we cannot say from regression results whether farmers who choose to participate in a network may be those already likely to adopt conservation practices, our mixed-methods design allows us to understand causality through multiple modes (Sayer 1992). Across surveys in 2013, 2017, and 2020, 71% of member farmers self-reported that they had adopted conservation practice(s) as a result of participation and during interviews, 76% of a sample of member farmers told us that PFI played a direct role in their transition to sustainable practices, or supported their continued use of these practices. In addition, other research conducted on PFI supports a causal relationship between involvement in PFI and the use of sustainable practices (Bell 2004; Warner 2007; Blesh and Wolf 2014; Carlisle 2016; Blesh and Galt 2017). In a study of Iowa grain farmers by Blesh and Wolf (2014), almost all listed PFI as an important resource for transitioning towards sustainability. The in-depth ethnographic research on PFI from Bell (2004) suggests that the dialogic culture that is a crucial element of PFI is a key way its members were able to transition to more sustainable practices.

Similar to Bell's (2004) findings, our research shows that building relationships within the network is an important component to adoption as farmers learn and vet ideas through these friendships and feel a sense of community and social support to try different practices. Our interview data show that PFI acts as much more than a channel for the diffusion of information. The network also provides an important source of encouragement and problem solving from like-minded farmers and network leadership, and a means through which to access resources. In the context of formal farmer networks broadly, more research would be useful to understand the ways in which networks encourage farmers to transition to conservation practices and the characteristics of farmer networks that are useful and desirable from farmers' perspectives. To gain the greatest societal benefit from formal farmer networks, more research is also needed to understand how to encourage greater and sustained participation, how to increase network reach to farmers on the periphery who may benefit most from information exchanged in networks (Granovetter 1973), and how to make networks work better for different types of farmers.

8. Conclusion

While our findings are not directly generalizable beyond PFI member farmers, several implications arise for strategies and policies to encourage greater use of conservation practices that may be applicable to farmers in other formal farmer-to-farmer networks in the US and to early adopters of conservation practices broadly. First, formal farmer-to-farmer networks may be a promising way to build and enhance farmers' technical capacity and provide the peer support necessary to create substantial progress toward sustainable agriculture at a grassroots level. The fact that engagement in PFI (both participation and length of time in the network) and adoption of conservation practices are strongly associated in our analyses, and that member farmers reported during in-depth interviews that PFI helped them to adopt or sustain adoption, suggests that there is a strong synergy between the two, regardless of causality. That early adopters participate frequently in this network means that it is a ripe avenue to support their transition to sustainable agriculture. Supporting these early adopters as role models is likely to catalyze wider-scale change.

Second, to create meaningful change in agriculture, it will be important to understand the most impactful ways of engaging farmers in learning about new practices. This is especially timely to consider given the growing use of remote learning formats brought on by the Covid-19 pandemic. This study finds that while network farmers value both independent and in-person ways of interacting in the network, regression and interview results point to the greater importance of in-person formats in adopting conservation practices. This finding is important as it contrasts other work elevating the importance of self-learning within early adopters compared to later adopters with whom face-to-face exchange is of greater importance (Rogers 2003; Dunn et al. 2016). Thus, networks and other farming organizations may benefit from prioritizing face-to-face programming that encourages relationship-building amongst members. Farmers in this study appreciated the benefits of remote and hybrid ways of learning through the Covid-19 pandemic, yet the strong desire to return to in-person learning formats suggests that remote options are beneficial, when possible, but returning to in-person offerings should be a priority.

The challenge remains that formal farmer networks do not exist everywhere and are limited by a lack of public and private support, and not all farmers have adequate information about networks or the ability to participate. Support is needed to help establish more formal farmer networks focused on conservation and to increase the reach of existing networks to conventional farmers, those in social circles who have not heard about them, and those who may not have the means to participate. We believe that government, land-grant university, and philanthropic investments in, as well as private sector partnerships with, formal farmer networks are a promising way to help farmers transition to more regenerative and resilient practices. Specialized farmer knowledge diffused through social networks is vital for developing farmers' adaptive capacity to respond to a changing climate, fluctuating markets, and socio-economic instability (Petersen-Rockney et al. 2021). Likewise, Cooperative Extension, embedded in university research, is vital for bringing knowledge from formal institutions to farmers. Creating and disseminating both farmer and formal scientific knowledge, a model unique to formal networks, likely creates synergies far greater than when the two remain separate.

References

Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50: 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Ban, A. W. van den. 1981. Interpersonal communication and the diffusion of innovations. In Extension Education and Rural Development.

Bandura, Albert. 1977. Social learning theory. Prentice-Hall Series in Social Learning Theory. Englewood Cliffs, N.J: Prentice Hall.

Barbercheck, M., K. Brasier, N. E. Kiernan, C. Sachs, and A. Trauger. 2014. Use of conservation practices by women farmers in the Northeastern United States. *Renewable Agriculture and Food Systems* 29(1): 65–82. https://doi.org/10.1017/S1742170512000348

Bates, H., and J. G. Arbuckle. 2017. Understanding predictors of nutrient management practice diversity in Midwestern agriculture. Iowa State University Digital Repository.

Baumgart-Getz, A., Prokopy, L.S., Floress, K. 2012. Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature. *Journal of Environmental Management* 96(1): 17–25. https://doi.org/10.1016/j.jenvman.2011.10.006.

Belknap, J., and W.E. Saupe. 1988. Farm family resources and the adoption of no-plow tillage in Southwestern Wisconsin. *Review of Agricultural Economics* 10(1): 13–23.

Bell, M.M. 2004. *Farming for us all: Practical agriculture and the cultivation of sustainability*. University Park, Pa: Pennsylvania State University Press, 2004.

Blesh, J. and R. Galt. 2017. Transitions to agroecological nutrient management practices in the USA Corn Belt: Principles, applications, and making the transition. In *Agroecological Practices for Sustainable Agriculture*, 85–126. London, UK: World Scientific Publishing. https://doi.org/10.1142/9781786343062_0004.

Blesh, J. and S.A. Wolf. 2014. Transitions to agroecological farming systems in the Mississippi River Basin: toward an integrated socioecological analysis. *Agriculture and Human Values* 31(4): 621–635. https://doi.org/10.1007/s10460-014-9517-3.

Brant, R. 1990. Assessing Proportionality in the Proportional Odds Model for Ordinal Logistic Regression. *Biometrics* 46(4): 1171–1178. https://doi.org/10.2307/2532457

Burnham, K. P. 2002. *Model selection and multimodel inference: a practical information-theoretic approach*. 2nd ed. New York, NY: Springer.

Campbell, J. T., T. M. Koontz, and J. E. Bonnell. 2011. Does collaboration promote grass-roots behavior change? Farmer adoption of best management practices in two watersheds. *Society and Natural Resources* 24(11): 1127–1141. https://doi.org/10.1080/08941920.2010.512358.

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.

Carlisle, L., M. Montenegro de Wit, M. S. DeLonge, A. Iles, A. Calo, C. Getz, J. Ory, K. Munden-Dixon, R. Galt, B. Melone, R. Knox, and D. Press. 2019. Transitioning to sustainable agriculture requires growing and sustaining an ecologically skilled workforce. *Frontiers in Sustainable Food Systems* 3(2019):96. https://doi.org/10.3389/fsufs.2019.00096.

Cheng, H. W. J. 2021. Factors affecting technological diffusion through social networks: A review of the empirical evidence. *The World Bank Research Observer*. https://doi.org/10.1093/wbro/lkab010.

Chiffoleau, Y., and D. Desclaux. 2006. Participatory plant breeding: The best way to breed for sustainable agriculture? *International Journal of Agricultural Sustainability* 4(2): 119–130. https://doi.org/10.1080/14735903.2006.9684795.

Cruse, M. J., M. Liebman, D. R. Raman, and M. H. Wiedenhoeft. 2010. Fossil energy use in conventional and low-external-input cropping systems. *Agronomy Journal* 102(3): 934–941. https://doi.org/10.2134/agronj2009.0457.

Dainese, M., E. A. Martin, M. A. Aizen, M. Albrecht, I. Bartomeus, R. Bommarco, L. G. Carvalheiro, et al. 2019. A global synthesis reveals biodiversity-mediated benefits for crop production. Science advances 5(10): eaax0121. DOI: 10.1126/sciadv.aax012

Davis, A. S., J. D. Hill, C. A. Chase, A. M. Johanns, and M. Liebman. 2012. Increasing cropping system diversity balances productivity, profitability and environmental health. *PloS One* 7(10): e47149. https://doi.org/10.1371/journal.pone.0047149.

Dunn, M., J. D. Ulrich-Schad, L. S. Prokopy, R. L. Myers, C. R. Watts, and K. Scanlon. 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.org/10.2489/jswc.71.1.29.

Durant, J. L., L. Asprooth, R. E. Galt, S. P. Schmulevich, G. M. Manser, and N. Pinzón. 2023. Farm resilience during the COVID-19 pandemic: The case of California direct market farmers. Agricultural Systems 204: 103532. https://doi.org/10.1016/j.agsy.2022.103532.

Fagerland, M. W., and D. W. Hosmer. 2016. Tests for goodness of fit in ordinal logistic regression models. *Journal of Statistical Computation and Simulation* 86(17): 3398–3418. https://doi.org/10.1080/00949655.2016.1156682.

Filson, G. C., S. Sethuratnam, B. Adekunle, and P. Lamba. 2009. Beneficial management practice adoption in five Southern Ontario watersheds. *Journal of Sustainable Agriculture* 33(2): 229–252. https://doi.org/10.1080/10440040802587421.

Foster, A. D., and M. R. Rosenzweig. 1995. Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy* 103(6): 1176–1209. https://doi.org/10.1086/601447.

Garbach, K., and G. P. Morgan. 2017. Grower networks support adoption of innovations in pollination management: The roles of social learning, technical learning, and personal experience. *Journal of Environmental Management* 204(2017): 39–49. https://doi.org/10.1016/j.jenvman.2017.07.077.

Gosnell, H., N. Gill, and M. Voyer. 2019. Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. *Global Environmental Change* 59(2019): 101965. https://doi.org/10.1016/j.gloenvcha.2019.101965.

Granovetter, M. 2005. The impact of social structure on economic outcomes. *Journal of Economic Perspectives* 19(1): 33–50. https://doi.org/10.1257/0895330053147958.

Granovetter, M.S. 1973. The Strength of Weak Ties. *American Journal of Sociology* 78(6): 1360–1380.

Hassanein, N. 1999. *Changing the way America farms: Knowledge and community in the sustainable agriculture movement*. Lincoln: U of Nebraska Press.

Hassanein, N., and J. R. Kloppenburg. 1995. Where the grass grows again: Knowledge exchange in the sustainable agriculture movement. *Rural Sociology* 60(4): 721–740. https://doi.org/10.1111/j.1549-0831.1995.tb00603.x.

Healy, G. K., and J. C. Dawson. 2019. Participatory plant breeding and social change in the Midwestern United States: Perspectives from the Seed to Kitchen Collaborative. *Agriculture and Human Values* 36(4): 879–889. https://doi.org/10.1007/s10460-019-09973-8

Hoffman, M., M. Lubell, and V. Hillis. 2015. Network-smart extension could catalyze social learning. *California Agriculture* 69(2): 113–122. https://doi.org/10.3733/ca.E.v069n02p113

Hogset, H., and C. B. Barrett. 2010. Social learning, social influence, and projection bias: A caution on inferences based on proxy reporting of peer behavior. *Economic Development and Cultural Change* 58(3): 563–589. https://doi.org/10.1086/650424.

Hunt, N. D., M. Liebman, S. K. Thakrar, and J. D. Hill. 2020. Fossil energy use, climate change impacts, and air quality-related human health damages of conventional and diversified cropping systems in Iowa, USA. *Environmental Science & Technology* 54(18): 11002–11014. https://doi.org/10.1021/acs.est.9b06929.

Iles, A., and R. Marsh. 2012. Nurturing diversified farming systems in industrialized countries: How public policy can contribute. *Ecology and Society* 17(4): 42. https://doi.org/10.5751/ES-05041-170442.
Khanna, M., O. F. Epouhe, and R. Hornbaker. 1999. Site-specific crop management: Adoption patterns and incentives. *Review of Agricultural Economics* 21(2): 455–472. https://doi.org/10.2307/1349891.
Kloppenburg, J. 1991. Social theory and the de/reconstruction of agricultural science: Local knowledge for an alternative agriculture. *Rural Sociology* 56(4): 519–548. https://doi.org/10.1111/j.1549-0831.1991.tb00445.x
Knowler, D., and B. Bradshaw. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32(1): 25–48. https://doi.org/10.1016/j.foodpol.2006.01.003.
Korsching, P. F., C. W. Stofferahn, P. J. Nowak, and D. J. Wagener. 1983. Adopter characteristics and adoption patterns of minimum tillage: Implications for soil conservation programs. *Journal of Soil and Water Conservation* 38(5): 428–431. https://doi.org/10.1016/0167-1987(85)90030-3
Kroma, M. 2006. Organic farmer networks: Facilitating learning and innovation for sustainable agriculture. *Journal of Sustainable Agriculture* 28(4): 5–28. https://doi.org/10.1300/J064v28n04_03.
Laforge, J. M. L., and S. M. McLachlan. 2018. Learning communities and new farmer knowledge in Canada. *Geoforum* 96(2018): 256–267. https://doi.org/10.1016/j.geoforum.2018.07.022
Laforge, J. M. L., and C. Z. Levkoe. 2021. The impacts of agroecology training within and beyond farmer training. In *Handbook on the Human Impact of Agriculture*. Edward Elgar Publishing.
Levy, M. A., and M. N. Lubell. 2018. Innovation, cooperation, and the structure of three regional sustainable agriculture networks in California. *Regional Environmental Change* 18(4): 1235–1246. https://doi.org/10.1007/s10113-017-1258-6.
Liverpool-Tasie, L. S. O., and A. Winter-Nelson. 2012. Social Learning and Farm Technology in Ethiopia: Impacts by Technology, Network Type, and Poverty Status. *The Journal of Development Studies* 48(10): 1505–1521. https://doi.org/10.1080/00220388.2012.693167.
Lubell, M., M. Niles, and M. Hoffman. 2014. Extension 3.0: Managing agricultural knowledge systems in the network age. *Society & Natural Resources* 27(10). Routledge: 1089–1103. https://doi.org/10.1080/08941920.2014.933496.
Lyon, A., M. M. Bell, C. Gratton, and R. Jackson. 2011. Farming without a recipe: Wisconsin graziers and new directions for agricultural science. *Journal of Rural Studies* 27(4): 384–393. https://doi.org/10.1016/j.jrurstud.2011.04.002.
McCullagh, P. 2019. Generalized linear models. Routledge.
Mekonnen, D. K., S. Yimam, T. Arega, K. Matheswaran, and P. M. V. Schmitter. 2022. Relatives, neighbors, or friends: Information exchanges among irrigators on new on-farm water management tools. *Agricultural Systems* 203(2022): 103492. https://doi.org/10.1016/j.agsy.2022.103492.
Montgomery, M. R., and J. B. Casterline. 1996. Social learning, social influence, and new models of fertility. *Population and Development Review* 22(1996): 151–175. https://doi.org/10.2307/2808010.
Napier, T. L., and T. Bridges. 2002. Adoption of conservation production systems in two Ohio watersheds: A comparative study. *Journal of Soil and Water Conservation* 57(4): 229–235.
Napier, T. L., and M. Tucker. 2001. Use of soil and water protection practices among farmers in three Midwest watersheds. *Environmental Management* 27(2): 269–279. https://doi.org/10.1007/s002670010148

Pampel, F. C. 2021. *Logistic regression: A primer*. Second edition. Thousand Oaks, California: SAGE Publications, Inc.
Pape, A., and L. S. Prokopy. 2017. Delivering on the potential of formal farmer networks: Insights from Indiana. *Journal of Soil and Water Conservation* 72(5): 463–470. https://doi.org/10.2489/jswc.72.5.463.
Park, T. A., and L. Lohr. 2005. Organic pest management decisions: a systems approach to technology adoption. *Agricultural Economics* 33(s3): 467–478. https://doi.org/10.1111/j.1574-0864.2005.00400.x
Patton, M. Q. 2002. *Qualitative research and evaluation methods*. 3 ed. Thousand Oaks, Calif: Sage Publications.
Petersen-Rockney, M., P. Baur, A. Guzman, S. F. Bender, A. Calo, F. Castillo, K. De Master, et al. 2021. Narrow and brittle or broad and nimble? Comparing adaptive capacity in simplifying and diversifying farming systems. *Frontiers in Sustainable Food Systems* 5(2021): 56. https://doi.org/10.3389/fsufs.2021.564900.
PFI. 2020. Practical Farmers of Iowa member survey.
PFI. 2022a. History. Practical Farmers of Iowa. https://practicalfarmers.org/about/history/. Accessed 17 April 2022.
PFI. 2022b. E-Mail Discussion Groups. Practical Farmers of Iowa. https://practicalfarmers.org/get-involved/connect-with-pfi/e-mail-discussion-groups/. Accessed 17 April 2022.
Phelps, C., R. Heidl, and A. Wadhwa. 2012. Knowledge, networks, and knowledge Networks: A review and research agenda. *Journal of Management* 38(4): 1115–1166. https://doi.org/10.1177/0149206311432640.
Prell, C. 2012. *Social network analysis: History, theory & methodology*. Los Angeles; SAGE.
Prokopy, L. S., K. Floress, D. Klotthor-Weinkauf, and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. *Journal of Soil and Water Conservation* 63: 300–311. https://doi.org/10.2489/jswc.63.5.300.
Prokopy, L. S., K. Floress, J. G. Arbuckle, S. P. Church, F. R. Eanes, Y. Gao, B. M. Gramig, P. Ranjan, and A. S. Singh. 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.org/10.2489/jswc.74.5.520.
Reimer, A., A. Thompson, L. S. Prokopy, J. G. Arbuckle, K. Genskow, D. Jackson-Smith, G. Lynne, L. McCann, L. W. Morton, and P. Nowak. 2014. People, place, behavior, and context: A research agenda for expanding our understanding of what motivates farmers' conservation behaviors. *Journal of Soil and Water Conservation* 69(2): 57A-61A. https://doi.org/10.2489/jswc.69.2.57A.
Rogers, E. M. 2003. *Diffusion of innovations*. 5th ed. New York: Free Press.
Rosset, P. M., B. Machín Sosa, A. M. Roque Jaime, and D. R. Ávila Lozano. 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: Social process methodology in the construction of sustainable peasant agriculture and food sovereignty. *The Journal of Peasant Studies* 38(1): 161–191. https://doi.org/10.1080/03066150.2010.538584.
Sawadgo, W., and A. Plastina. 2022. The Invisible Elephant: Disadoption of Conservation Practices in the United States. Choices. Quarter 1.
Sayer, A. 1992. Problems of explanation and the aims of social science. In Method in social science: a realistic approach, 2nd ed., 211–258. London; Routledge. https://doi.org/10.4324/9780203163603.
Schram, S. G. 2010. Cooperatives: Pathways to Economic, Democratic and Social Development in the Global Economy. The U.S. Overseas Cooperative Development Council. The U.S. Overseas Cooperative Development Council.

Singh, A., B. MacGowan, M. O'Donnell, B. Overstreet, J. Ulrich-Schad, M. Dunn, H. Klotz, and L. Prokopy. 2018. The influence of demonstration sites and field days on adoption of conservation practices. *Journal of Soil and Water Conservation* 73(3): 276–283. https://doi.org/10.2489/jswc.73.3.276.

Soule, M. J., A. Tegene, and K. D. Wiebe. 2000. Land tenure and the adoption of conservation practices. *American Journal of Agricultural Economics* 82(4): 993–1005. https://doi.org/10.1111/0002-9092.00097.

Šūmane, S., I. Kunda, K. Knickel, A. Strauss, T. Tisenkopfs, I. des I. Rios, M. Rivera, T. Chebach, and A. Ashkenazy. 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies* 59(2018): 232–241. https://doi.org/10.1016/j.jrurstud.2017.01.020.

Tamburini, G., R. Bommarco, T. Wanger, C. Kremen, M. Heijden, M. Liebman, and S. Hallin.

2020. Agricultural diversification promotes multiple ecosystem services without compromising yield. *Science Advances* 6(45): eaba1715. https://doi.org/10.1126/sciadv.aba1715.

Thessen, G., C. Adamson, and B. Parks. 2020. *2020 Iowa Agricultural Statistics*. USDA, National Agricultural Statistics Service Upper Midwest Regional Office.

Thomas, J. K., H. Ladewig, and Wm. A. McIntosh. 1990. The adoption of integrated pest management practices among Texas cotton growers. Rural Sociology 55(3): 395–410. https://doi.org/10.1111/j.1549-0831.1990.tb00690.x.

Trauger, A. 2009. Social agency and networked spatial relations in sustainable agriculture. *Area* 41(2): 117–128. https://doi.org/10.1111/j.1475-4762.2008.00866.x

Ulrich-Schad, J. D., S. García de Jalón, N. Babin, A. Pape, and L. S. Prokopy. 2017. Measuring and understanding agricultural producers' adoption of nutrient best management practices. *Journal of Soil and Water Conservation* 72(5): 506–518. https://doi.org/10.2489/jswc.72.5.506.

USDA NASS. 2017. *2017 Census of Agriculture*. Washington, DC: USDA National Agricultural Statistics Service.

Valente, T. 1996. Network models of the diffusion of innovations. *Computational and Mathematical Organization Theory* 2(1995): 163-164. .

Warner, K. 2007. *Agroecology in action: extending alternative agriculture through social networks*. Food, Health, and the Environment. Cambridge, Mass.: MIT.

Wellman, B. 1983. Network analysis: Some basic principles. *Sociological Theory* 1: 155–200. https://doi.org/10.2307/202050

White, E. 2021. 3 Insights about farmer-to-farmer learning communities from our work on America's conservation ag movement. Trust In Food. 14 June 2021. https://www.trustinfood.com/2021/06/14/3-insights-about-farmer-to-farmer-learning-communities-from-our-work-on-americas-conservation-ag-movement/

Wilson, R. S., G. Howard, and E. A. Burnett. 2014. Improving nutrient management practices in agriculture: The role of risk-based beliefs in understanding farmers' attitudes toward taking additional action. *Water Resources Research* 50(8): 6735–6746. https://doi.org/10.1002/2013WR015200

Wypler, J. 2019. Lesbian and Queer Sustainable Farmer Networks in the Midwest. *Society & Natural Resources* 32(8): 947–964. https://doi.org/10.1080/08941920.2019.1584834

Chapter 2 Transforming the Corn Belt: A recipe for collaborative, farmer-driven research and diffusion of innovation

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Abstract

Practical Farmers of Iowa is a unique and longstanding farmer-to-farmer network with a history of driving the use of sustainable practices like cover cropping and low-chemical-input farming in the heart of the US Corn Belt. PFI was at the center of the launch of participatory, on-farm agricultural research in the 1980s, and has grown to a network of over 6,000 farmers, researchers, advocates, and professionals using farmer-driven research and knowledge sharing to change deeply embedded norms of industrial farming in the region. Through in-depth interviews with 26 current and former member farmers, we explore the role of PFI in the adoption of conservation practices, identify its "recipe" of success—the combination of the most important elements of the network according to its member farmers, and discuss issues of how the network should navigate current and future challenges. Farmers told us that PFI generates and shares information, provides a supportive community, acts as a long-distance coffee shop for alternative-minded farmers, and serves as a catalyst for change in the region. The most important aspects of PFI that farmers said supported them in adopting conservation practices were its diverse membership, autonomous functioning, culture of openness, and non-ideological nature. Moving forward, the network faces questions regarding 1) whether to place its focus on corn and soybean

farmers or spread its efforts across a diversity of types of farmers and 2) how to build trust and communication between farmers as they become more geographically distant due to increasing farm consolidation. An understanding of how the network functions can enable a deeper understanding of the role of peer-to-peer networks in driving transformative change in agricultural practices and how they can be shaped to create the most impact for farmers.

Keywords: Farmer networks, peer to peer networking, adoption, conservation practices, Corn Belt, case study

1. Introduction

Despite growing research, outreach, and advocacy on sustainable agriculture, little has changed in the US Corn Belt over the last several decades. For example, cover crops, a low cost and effective way to improve soil health and water quality, are planted on less than 4% of cropland in Iowa (USDA NASS, 2017), a state in the heart of the Corn Belt. The region as a whole has the lowest crop diversity in the country (Aguilar 2015) and, in Iowa, corn and soybean acres have been slightly increasing since 1997 (USDA NASS, 2017). As little changes, the effects of industrial farming practices accumulate in soils, waters, and bodies and the need for more effective ways to encourage the adoption of sustainable practices has become paramount.

Yet, as implied from the slow spread of many sustainable practices, changing embedded industrial farming practices to regenerative ones is complex. While the benefits to soil health and productivity of conservation practices are well documented (Chaplin-Kramer et al., 2011; Dainese et al., 2019; Tamburini et al., 2020), farmers contend with a stream of social, structural, economic, and ecological barriers to transition—social pressure to conform to existing ways of production (Ranjan et al., 2020), unsupportive policies (Iles and Marsh, 2012), a lack of markets for alternative crops

(Roesch-McNally et al., 2018), a need for new equipment and knowledge (Arbuckle & Ferrell, 2012), and greater management and system complexity (Roesch-McNally et al., 2018), among others. Meanwhile farmers' high debt to income ratio (3.2 in 2021[7]) and growing debt loads and production costs (USDA, 2023) make considering practices with payoffs that accrue in the mid- to long-term difficult (Blesh and Galt, 2017). Much of the efforts to expand the adoption of agricultural conservation practices focuses on addressing barriers through university research and extension, governmental support programs, and non-profit assistance. Still, these solutions have limitations: university research is increasingly funded by agro industries (Pardey et al., 2015); research and extension face declining funding (Nelson and Fuglie, 2022; Wang, 2014); policies and programs (e.g., Farm Bill programs, county level watershed group cost share) can be difficult to pass and implement and are subject to change as funding availability, political leadership, and popular opinion shift; and non-profit support and assistance can lack leadership from, and relationships with, farmers, resulting in missing perspectives necessary to best respond to their audiences.

Often missing from the common suite of efforts to support, encourage, and empower farmers towards a path of conservation is the importance of the social environment. Because we do not make decisions in a vacuum, our decisions are not independent of those around us. Instead, we are impacted by our relationships and the social context in which we live. The field of psychology has long elevated the role of social norms and learned habits in explaining human behavior (Heimlich and Ardoin, 2008; Klöckner, 2013). Social learning theory (Bandura, 1977) suggests that human behavior is learned through observation and that changing societal norms can be achieved through socially learned and reinforced behaviors in the community and within the context in which the behavior can be used. Several prominent theories in behavior change including the Theory of Planned Behavior (Ajzen, 1991) and the Theory of Reasoned Action (Ajzen & Fishbein, 1980;

[7] This statistic was calculated by the authors using total farm debt and net cash farm income for the US.

Fishbein and Ajzen, 2010) echo the importance of normative influences on human behavior. They suggest that behavior is guided by intention and intention is determined by social pressure to perform the behavior, along with attitudes towards the behavior and perceived ability to carry out the behavior. These theories have been extended to show that social norms relative to the behavior — particularly from peer groups — can influence intention to perform the behavior (Bonke and Musshoff, 2020; Terry et al., 1999). This aligns with existing empirical research showing that membership in an agricultural organization can help predict adoption (Bates and Arbuckle, 2017; Belknap and Saupe, 1988; Korsching et al. 1983). Evident across each of these theories is that creating positive perceptions of the outcomes of performing the behavior, and increasing social support for the behavior, are needed for successful interventions (Kasprzyk et al., 1998).

Given the nature of farming and the visibility of one's farming decisions, social support is a particularly important factor in farmer decision making since going against established norms can involve disapproval from neighbors (Bell, 2004). Networking between farmers is an effective way to spread conservation innovations that harnesses the power of social influence to drive behavior change. Broadly, we are more likely to perform a behavior when those in our social network are also performing the behavior (Prell, 2012; Rogers, 2003). In networks, farmers can learn by observing and socially interacting with other farmers implementing conservation practices while providing support to go against established norms (Kroma, 2006; Gosnell et al., 2019). Strengthening and expanding social networks of early adopters of conservation practices can help change societal norms regarding these practices as farmers learn and observe from those already using them.

To realize the potential of farmer networks, it is important to understand what makes networks effective at creating change. Only a few studies of farmer networks explore the functional mechanisms of farmer networks including Kroma (2006); Bell (2004); and Hassanein (1999). Responding to calls for a better understanding of contemporary social networks in farmer decision-making and how to replicate the mechanisms of successful networks (Reimer et al., 2014), this study builds upon each of these studies by explicitly uncovering the purpose and desirable characteristics of farmer networks from the farmer perspective. We do so by exploring in-depth one prominent farmer network, Practical Farmers of Iowa (PFI) asking 1) What are the origins of the PFI network? 2) What is the role of the PFI network in supporting farmers to adopt conservation practices? and, 3) What is the network's "secret sauce", or the most important aspects of the network that work well for farmers? To answer these questions, we begin by providing an overview of farmer-led research and farmer networks in the US. Then, we explain the history of PFI and its current operation. Next, we summarize findings from in-depth interviews with current and former member farmers on the role of PFI in the adoption of conservation practices, the most important facets of the network according to its member farmers, and how to move forward in the network. Finally, we ground our findings in the existing empirical literature on farmer-to-farmer networks and summarize the implications.

2. Farmer networks: a model of farmer-led research and diffusion of innovation

Land-grant universities have traditionally operated within a conventional scientific paradigm in which scientific research is seen as the source of innovation (Röling, 1996). Innovation and technologies are produced and disseminated using a top-down pedagogical approach from researcher to extensionist to farmer based on the theory of diffusion of innovation (Lubell et al., 2014; Warner, 2007; Rogers 2003; Vanclay and Lawrence, 1994). This system produced two main downfalls: (1) the information produced has not always been a priority for farmers, especially those using nonproprietary and low-input systems, and (2) the legitimacy of farmer knowledge has been devalued (Altieri, 1995). It has become increasingly recognized by the academy and cooperative extension that facilitating a transition to sustainable agriculture requires a more inclusive and network-based approach to working with farmers (Lubell et al., 2014; Warner, 2008; Röling 1996). While farmer-driven research priorities and participatory research methods were initially approached with skepticism from university researchers according to one of the first books to try to validate it (Chambers et al., 1989), such approaches and methods are becoming more commonplace (Dawson and Goldberger, 2008; Welch et al., 2016).

Still, these participatory methods are led by the scientist or formal expert, who are often at the center of the production and dissemination of knowledge. Peer-to-peer farming networks, on the other hand, support farmers to develop and share place-based, practical knowledge (Hassanein, 1999). The knowledge generated and exchanged in these networks produces locally adapted solutions to complex agricultural problems without relying on increasingly scarce public research funds (Holt-Giménez, 2006). Farming networks are well positioned to diffuse information as farmers generally learn better and are more likely to adopt new practices through peer learning (Foster and Rosenzweig, 1995; Prokopy et al., 2019). In the process of creating and sharing information, farmers in networks form social support systems that encourage fellow farmers during their transition to sustainable practices (Blesh and Wolf, 2014).

As public funding for research and extension in agriculture continues to decline and becomes more influenced by private industry (Gupta et al., 2019; Pardey et al., 2015), the role of alternative farming networks grows in importance for the independent generation and diffusion of place-based agroecological solutions alongside institutional knowledge. Alternative farmer networks are generating grassroots, farmer-driven research and diffusing information among members. As self-production of agricultural knowledge is inherently connected to farmer agency (Dolinska and d'Aquino, 2016), networks lower reliance on knowledge from public institutions or the private sector by operating outside of them (Hassenein, 1999), or as equal partners alongside them (Asprooth, 2023, Šūmane et al., 2018).

PFI and the origins of a model of collaborative, farmer-led research

PFI was founded in 1985 during a critical time in US agriculture — the height of the US farm crisis. At the time, the widespread solution to collapsing grain prices was to capitalize on economies of scale by expanding production and to increase yields through chemical-intensive, high-input practices (Lighthall and Roberts, 1995). With the vast majority of farmers headed this direction, university research and extension followed suit aiming to serve this farming majority (Jerry DeWitt, 2020, pers. comm.[8]) and maintain funding from agrochemical companies (Bell, 2004).

A subset of mid-scale, diversified farmers, however, saw an alternative path out of the farm crisis. Instead of steadily increasing acres and external inputs, these farmers believed a reduction of costly inputs and improved use of internal resources was the way to economic vitality (Lighthall and Roberts, 1995). Early PFI members were confident that their alternative way of farming could be profitable, and to realize this, they needed more research on how the practices worked. But without funding from agro-input industries or will on the part of Iowa State University (ISU), the state 1862 land-grant institution, the questions raised by these farmers were not being addressed by the university (Jerry DeWitt, 2020, pers. comm).

Left behind by university-led agricultural research and innovation of the 1980s, several farmers began answering their questions themselves through on-farm experimentation (Lighthall and Roberts, 1995; Warner, 2007). Set in motion by an idea from Dr. Chuck Francis, an agronomy professor at the University of Nebraska, they began using a simplified research design that was easy to reproduce and allowed farmers to be in charge of the entire process from conception to execution to analysis. The technique, called strip trials, used replicated side-by-side comparisons of a

[8] Jerry DeWitt was an extension entomologist at Iowa State University and held the role as the Associate Dean of the Iowa State Extension Service and director of the Leopold Center for Sustainable Agriculture.

treatment and control, allowing for statistically valid results (Rosman, 1994; Warner, 2007). With the help of PFI collaborator and ISU graduate student at the time, Rick Exner, the trials evolved to use randomized whole field strip comparisons. PFI began drawing in audiences at field days as big, and at times bigger, than ISU (Jerry DeWitt, 2020, pers. comm).

As the data from PFI's strip trials proved reliable, factual, and useful, ISU began to recognize PFI's trials on working farms as scientifically valid (Bell, 2004). PFI's on-farm research grew and the term "strip trials" began being adopted across the country. While PFI's divergent farming practices and unconventional research design led to a tense relationship at times between PFI farmers and ISU professionals, over time, farmers were increasingly accepted as legitimate research partners (Jerry DeWitt, 2020, pers. comm). Farmer-led research started to become more visible and integrated with normal extension and research activities at ISU. Jerry DeWitt, the Associate Dean and Agriculture Program leader at the time, described the change in the minds of extension professionals: "Okay, these are good farmers. They're not some crazies you read about. These are just darn good farmers" (Ibid).

With the intention of working with universities, not against them, the collaboration between PFI and ISU sent a message that cooperative extension can reach out and work effectively with a farmer-led nonprofit. ISU was recognized nationally as a model for cooperating with a nonprofit organization, arguably launching participatory agricultural research in the US (Jerry DeWitt, 2020, pers. comm; R. Exner, 2020, pers. comm[9]). For the first time in the US[10], university researchers were sitting down with farmers and asking them about the kinds of research that should be conducted,

[9] Rick Exner was PFI's Farming Systems Coordinator from 1989 to 2009, PFI's first employee hired initially to help farmers conduct the statistical analysis and compile the findings from research trials.
[10] The Tuskegee Agricultural Farmers' Institutes run by Dr. George Washington Carver is an earlier example of famer-inclusive agricultural research. Dr. Carver distributed information to farmers written in non-technical terms, gave practical demonstrations guided by a farmer advisory board, and farmers were "encouraged to relate their personal experiences in applying these methods and principles" (Jones, 1975 p.259; Crosby, 1986; Hersey, 2006). ISU and PFI went further to integrate farmers as partners in conducting research.

farmers trialed practices they were interested in on their own farms, and all parties discussed the results (Jerry DeWitt, 2020, pers. comm). The model is now used or aspired to around the country by farming networks and university cooperative extension, including the Ohio Ecological Food and Farming Association and Ohio State University Extension and the Sustainable Farming Association of Minnesota and the University of Minnesota Extension.

PFI had launched farmers into university-led research and in turn brought researchers into the farmer network, creating a model for the rest of the country to follow. Today, PFI functions as more than an organization for on-farm research, although on-farm research and farmer-to-farmer learning are still at the heart of its work. In exchange for an annual fee, members are eligible for support programs (e.g., cost-share and mentorship), receive a quarterly magazine, have access to email discussion groups, and receive event discounts in an effort to enhance the member's inclusion and accessibility to the wide-reaching network. Its membership has grown to a diverse group of over 6,000 farmers, researchers, advocates, and professionals in 38 states. The majority of PFI member farmers still grow corn and soybeans, but the group has expanded to include a range of diversified operations. While programs and resources are crafted to meet the diverse needs of the membership, PFI's intention is to build a network based on shared values rather than particular farm characteristics.

The mission of the organization is to "equip farmers to build resilient farms and communities" through its values of "welcoming everyone; farmers leading the exchange of experience and knowledge; curiosity, creativity, collaboration and community; resilient farms now and for future generations; and stewardship of land and resources" (PFI, 2023a). As a farmer-led organization, PFI members farmers make up a majority of the board of directors and can sit on program committees, members farmers decide on the topics for on-farm research and carry out the trials, and the staff acts on behalf of the membership to plan programming and outreach activities.

Practical Farmers of Iowa as a case study

This study explores the role of formally organized farmer networks in the adoption of conservation practices using the longstanding network of PFI as a case study. We focus on PFI as an intrinsic case study, or an in-depth study of a particularly unique situation (Creswell, 2018), due to its size, uniqueness, and recognition in the Corn Belt region. Few other farmer networks in the US conduct state-wide on-farm research, nor have generated such a large membership base, programming, and staff as well as research interest. We build upon existing quantitative work demonstrating a relationship between greater participation in the PFI network and greater adoption of conservation practices ([Authors], 2023) and qualitative inquiry into the role of the network and its farmers in cultivating sustainability (Bell, 2004; Blesh and Galt, 2017; Carlisle, 2016; Warner, 2007). Bell (2004) provides a compelling account of how the unique dialogic culture of PFI enabled farmers to develop ever-changing solutions to making farming more economically, socially, and ecologically sustainable. We delve deeper into PFI farmers' experience with the network by explicitly examining the elements that draw farmers to engage in a network that enables them to innovate away from entrenched agricultural norms.

The findings of this study are not meant to be generalized to other farming groups but to represent the unique attributes and history of one network that has achieved relative success (membership size, programs, staff) and recognition in the US. Understanding the factors that make PFI impactful for farmers can help to generate theories of the causal mechanisms underlying the impact of farmer networks on farmer decision making. It can also help emergent networks, established networks, and those in areas without networks understand how to scale up, modify, or build a network based on what has worked well in the case of PFI.

3. Study Methods

In-depth, semi-structured interviews with PFI member farmers took place from July to December of 2020. Members of the research team included two independent scholars external to the PFI organization who collected and analyzed the data and one member of the PFI staff who, together with the other authors, helped to design the study, generate research questions, connect to PFI internal data, and interpret results. The PFI staff person has since moved on and has been employed elsewhere during manuscript writing. All authors helped to write the manuscript, with the lead author developing the first draft of the paper and the independent scholars writing the results section. No organizational mandate was given to conduct the research; instead, the research team worked with the organization to develop research questions that were both of interest to the organization and of broader interest to generating knowledge on farmer networks. The PFI organization had no editorial oversight and the research team had complete autonomy over publishing results. We also note that the two independent scholars have both been involved in projects that included PFI, and by becoming familiar with the organization, have come to admire its origins and workings. As such, they bring an appreciative form of inquiry to the work, or a focus on what is working well in an organization with an eye towards replicating this success in the future (Coghlan et al., 2003).

Two PFI member farmers piloted the interview protocol to refine questions. Farmers were told in the beginning of the interview that PFI was funding this research, however, the interviewer (the first author) was independent and all information from the interviews would be published or relayed back to PFI only after removal of all individual identifying information. Interview questions related to this paper focused on their and experience with and thoughts on the PFI network. Several questions expanded upon those asked in the 2020 PFI member survey. Member surveys are distributed to all members every three to four years via email and collect information about members' farms, farming practices, goals, feedback about past PFI programming, and future priorities for PFI. While the interviews were conducted during the first year of the Covid-19 pandemic in the US (from July–December 2020), we asked farmers about their experiences in the network prior to the pandemic to gain a general idea of how the network functions.

We sampled farmers to interview from the 534 members who filled out a 2020 PFI member survey using a stratified, maximum variation sampling technique (Patton, 2002) to understand perspectives from a variety of member farmers. First, we limited the sample to members who 1) were currently farming, 2) grew row crops (corn and/or soybeans) and, 3) resided in one of the following Corn Belt states: Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin. While PFI is a diverse organization that includes farmers involved with horticulture, orchards, and animal husbandry, we focus on corn and soybean growers as this group has the largest environmental impact on the landscape and because they are representative of a majority of PFI's membership. PFI members are primarily located in Iowa (82%), however, there are members throughout the Corn Belt. PFI members also exist in other parts of the country and overseas, however we limited our scope to the Corn Belt to understand how PFI is affecting farmers in the region where the majority of its members reside.

Next, we divided member farmers into four groups based on two axes: 1) their level of adoption of conservation practices and 2) their involvement in the PFI network. We then randomly sampled within each of these four groups. This division uses two indices developed by Asprooth (2023) — one measuring the levels of adoption of conservation practices and another measuring participation in the PFI network based on member responses to the 2020 member survey. We included a subset of farmers in the sample prior to random selection who responded to the 2017 PFI member survey but had not renewed their membership as of 2020 to gain a potentially more critical perspective — from non-renewing members — on the network.

Finally, after finding our sample to be composed of primarily participants who self-identified as men, we recruited and interviewed two additional women-identifying farmers through snowball sampling. We chose to include additional women in the study due to evidence showing that even if a woman is a considerable decision-maker on a family farm led by a mixed-sex couple, she may not identify as a "farmer" (Bell, 2004; Brasier et al., 2014; Sachs, 1996). In addition, women are underrepresented in agricultural survey research (Eells and Soulis, 2013). Therefore, while women may contribute to decisions around participation in farming organizations like PFI, they may also leave responding to farming surveys up to the men in the household and have been missed through the initial PFI surveying effort. For these reasons, we elevated women's voices and perspectives on the PFI farming network.

Seven hundred and eighty-five of PFI's 1,941 memberships, both individual and household, responded to the 2020 member survey for a response rate of 40%. Of those contacted from the survey for an interview, 71% agreed and were interviewed. Within the additional female farmers contacted through snowball sampling, 63% were interviewed. The farmers we interviewed represent 1.3% of member households in the PFI network. Interviews lasted between 45 minutes to an hour and a half and were conducted via Zoom or in person depending on location and farmer preference. After interviewing 26[11] member farmers, themes began to reoccur in farmer responses, and we reached a level of acceptable saturation. In total, we interviewed 22 current and 4 former member farmers.

[11] Two farmers were interviewed together, and their responses are counted as one in the findings because they took turns answering questions.

Interview questions and coding were developed using a grounded theory approach according to Corbin and Strauss (1990). We adhered to a standardized interview protocol[12] throughout each interview, and as themes emerged from participants, more specific questions were incorporated into subsequent interviews. This allowed us to verify whether the theme was shared across farmers, even if it was not mentioned initially. Interviews were recorded and audio was transcribed using Rev transcription service and a total of 645 pages were transcribed. Given the scarcity of information on network functioning, we used a purely inductive approach to analyzing interview data. In other words, we did not guide our analysis based on existing theory or research findings, but instead let themes emerge from the ground up and compared them to the literature post-analysis (Creswell, 2018). Data were analyzed in NVivo software (version 1.6.2), and two rounds of coding took place: open coding that identified categories of information and axial coding that connected the category codes to larger themes. Themes were identified that emerged across multiple respondents and verified by conducting keyword searches of the transcripts. All themes that emerged are included in the results section. We did not differentiate between current and former member farmers in our results due to the lack of distinction in responses between the two groups[13].

Each category that emerged is illustrated by quotes from interviews. The interview data were triangulated with participant observation during PFI events (workshops and field days) and listservs during the summer of 2020, review of PFI website and external facing materials, analysis of the 2013, 2017, and 2020 member survey data, and a search of news media related to the network. We used respondent validation to ensure that our findings were accurate and reflective of participant's experiences (Crowe et al., 2011). Participants were sent a draft of the manuscript in January 2023

[12] Interview protocol is available on request from the corresponding author.

[13] We also asked former members why they did not continue their membership; answers were generally not about programming or culture, but about time and resources, and therefore less relevant to the specific research questions of this study.

and invited to review our interpretation of the interview results. Eleven of the 26 participants responded and each provided edits or reported that the paper accurately portrayed their perspectives and captured the qualities of the organization and its members. The study received approval for research involving human subjects from the University of California, Davis Institutional Review Board.

4. Findings

Characteristics of survey respondents

The interviews included 6 women and 20 men with ages ranging from 30 to 72 years old (mean=57), all identifying as white. All but three participants lived and farmed in Iowa, with the remaining farmers from the surrounding Corn Belt states of Illinois, Nebraska, and Wisconsin. This coincides with the geographic dispersion of the general farming membership of PFI. The majority of farmers in the sample primarily produce corn and soybeans and receive, on average, 79% of their income from these two crops. Thirty-five percent of farmers in the sample used solely corn and soybean rotations and the rest used extended rotations of three or more crops. Forty-two percent had integrated crop-livestock operations. The average acres operated (owned and rented) by farmers in the sample was 580 acres and the median acres operated was 400 acres. Farmers were evenly distributed in their experience farming across 6-11 years, 11-30 years, and 30+ years, with fewer (2) farmers in the sample farming for 5 or less years. Interviewed farmers differed slightly compared to those who took the 2020 PFI member survey. Farmers in the survey sample relied less on corn and soybeans (15% solely planted corn and soybeans), had more livestock (56%), had been farming longer (more frequently 30+ years), and farmed more acres (mean=835 acres). Interviewed farmers had been members of PFI between five months to 31 years with an average of 11 years of membership for current members. Former member farmers who had not renewed their membership had been members for one year or less.

The role of PFI in the adoption of conservation practices

To answer our first research question about the role of PFI in supporting farmers to adopt conservation practices from the farmer perspective, we sourced relevant responses from questions about why they joined PFI, the most important parts of the network, and how the network impacted them. Four main categories emerged during coding of transcripts: generate and share information, provide support and instill confidence to try new things, connect farmers across geographic distances ("long-distance coffee shop"), and catalyze change towards a transition to sustainable agriculture. Each subsection below discusses the categories in further detail.

Generate & share accessible information. The most frequently mentioned role of PFI brought up by farmers (84% of the sample) was to generate and share information about sustainable and economical agricultural practices. Conservation agriculture deviates from standardized industrial production, requiring a more nuanced set of recommendations and techniques that vary by agroecological conditions (Lyon et al., 2011; Warner, 2007). Yet, public funding and research in the US is currently focused on chemically intensive, industrial agriculture (DeLonge et al., 2020, 2016), and the private sector has little incentive to conduct research on practices that require less purchased inputs (Clancy et al., 2016). This has left a gap in information on sustainable practices for farmers and farming organizations to fill (Lyon et al., 2011).

Farmers discussed a core role of PFI staff and member farmers as generating new ideas on how to farm sustainably, producing information through field trials, and sharing personal experiential knowledge at events and through online formats. Two farmers summarized these points below:

> Farmer 6: It was the information I got that was different. It wasn't geared toward commercial [sales]. It was a different angle. It was a lot more sustainable, a little bit more environmental, and a lot more collaborative.
>
> Farmer 23: It's a big umbrella and just a lot of ideas going around and those ideas are catching people's attention.

Farmers also told us how PFI distills information in ways that are easy to access and understand, explained by two farmers as:

> Farmer 13: They're trying to keep it simple, and so it's in language that farmers can understand better. They put it in a format in such a way that it's really easy to access and read.
>
> Farmer 15: Their website has a ton of information. If I wanted to look for something, I'd find it there. Their Facebook page has a lot of information. And I get a newsletter, and I'm part of their listserv, so I get a lot of the information. I mean, all these networks have these mechanisms, so I mean it's not like they're unique in that, I guess, but I just felt like they felt more approachable, easier to access.....But it can get pretty heavy, and the best way to get your research across is to make it simple, easy to understand terms and usable, and I think that's what PFI does with their research that makes them a valuable resource.

Provide a supportive community. Going against current industrial agricultural practices by using conservation practices can be an isolating act, and one that involves a long-term commitment with greater initial risk and labor (Carlisle et al., 2019). The second most frequently mentioned role of PFI (discussed by 48% of farmers) said that PFI provides emotional support, in addition to technical support, to take this path. PFI staff and fellow farmers provide encouragement, instill confidence to try new practices, and reaffirm conservation behaviors. Several farmers expressed their general reluctance to try new things and the confidence and encouragement PFI gave them to do so:

> Farmer 3: I probably wouldn't have used cover crops quite as much if hadn't seen PFI members doing it for a long period of time. That gave me confidence to try.
>
> Farmer 6: Farmers are sometimes reluctant to try something out, especially along a gravel road or a highway where everybody can see. You need a safe group of people to work [with], to confide in when you try new things… Providing that support, in case of failure on an experiment or something, you don't feel so bad. You can say, well, other people have done this too. Not everybody's brave enough to try new things. A lot of people are just really hesitant to stick their neck out or try new things or be talked about in the coffee shop…(PFI) provides a network of people that you can talk to about these things and they provide encouragement.
>
> Farmer 11: They've probably strengthened and given me more confidence on the steps I've taken on soil health. They've given me much more confidence in my rotations, and my nutrients.

Trialing a new practice, however, does not always lead to sustained adoption. According to aggregate data from the US Department of Agriculture (USDA), two heavily promoted conservation practices—cover cropping and no-till farming—experienced 5% and 27% ratios of disadoption, or discontinued use, from 2012 to 2017, respectively, across counties in the Heartland region (Sawadgo and Plastina, 2022). Farmers pointed to PFI playing an important role in encouraging continued use of conservation practices by re-enforcing their decisions to try new practices and supporting them to stay on the path towards conservation agriculture:

Farmer 16: They have solidified some things that, yes, I think I'm going down the right track. Or maybe I've learned something that's tweaked the practice a little bit.

Farmer 19: The role of PFI in my life was to reinforce the decisions that I was making…I was already headed down the road toward a more diversified production, longer rotations, soil conservation, protecting the quality of the water…But PFI just kind of gave me the validation and reinforcement that I felt like I needed to keep doing that.

Given the dominance of conventional farming practices in the region, finding other like-minded farmers to connect with can be challenging and many farmers noted that the support from PFI is particularly important as it came from a community of individuals with whom they did not feel marginalized for farming differently:

Farmer 18: We're not farming like the pages of Successful Farming or Farm Journal. So, you need the peer group of friends to kind of rely on for working through your problems or even support from them.

Farmer 19: Being able to talk to other farmers who are interested in the same kinds of practices without feeling like you're an alien, not having to defend constantly your choices…or feel defensive about your farming choice of practices.

Farmer 20: The social aspect of being supported doing something crazy…was really important. If you're going to be adopting new practices, you need to have a social network, so that you don't feel alone.

*Serve as a catalyst for change***.** Throughout interviews it was also clear that many farmers (mentioned by 24% of farmers in the sample) believed PFI plays a broader role in the transition to sustainable agriculture in the Corn Belt. Farmer 3 said, "PFI has been such a catalyst. I think that's maybe the best term, a catalyst. If we didn't have PFI, I think we would not be as much involved in thinking about sustainability." There was an overarching sentiment that PFI serves as a catalyst, or a force increasing the rate of change in the region, by presenting alternatives to the farming status quo and increasing awareness of these alternatives. Two farmers reflected:

> Farmer 6: …it's just a bunch of farmers doing their own thinking and saying, "well, you don't really have to do this. You don't have to buy this. You can do this." It was alternative viewpoints that you hear. It just attracts a different group of people that just have a different mindset about agriculture, just probably more independent thinkers.
>
> Farmer 12: I watched the videos and things, and they're presenting people with these other points of view. I think that's pretty important to say okay, I'm planting cover crops, or I'm using a cover crop roller, or I'm planting multi-species…[or] my cattle are grazing in there in the wintertime.

Four farmers specifically mentioned that PFI helped them to question conventional agriculture by "thinking outside of the box" about how to farm. Farmer 13 explained:

> [PFI] made me think outside the box and giving me the idea that conventional wisdom isn't always what's going to work. Question some of the long-held beliefs by the experts in industrial agriculture that the solution isn't always in a jug or a particular herbicide, that sometimes [it] takes more cultural practices (practices to manage fertility, pests, and weeds that do not involve chemicals) to really make things work better.

Act as a long-distance coffee shop. Facilitating connections with other farmers and providing the support of a community of like-minded farmers across long distances was an important role that several farmers (16%) identified PFI as filling. With fewer farmers on the land due to increasing farmland consolidation (Hendrickson et al., 2020), and even fewer farmers that use alternative practices, the distance to like-minded farmers can be prohibitive to networking. Farmers in the study said that only 10-25% of like-minded farmers in their network lived within 50 miles and many wished they had more local support. Farmer 2 explained:

> …in our specific geographic area, there aren't a lot of farmers that are doing sustainable practices like we're interested in…Generally, it's hard to ask advice from... or information from the neighbors when they're conventional minded with their cropping systems and things like that. And yeah, it's just there isn't a lot of local support.

Farmer 21 echoed this sentiment and connected the role of PFI:

> In Iowa there's not a ton of people doing what we're doing. So, it's not like it's just the farmer down the road. It's more like it's the farmer a county down from you. PFI is crucial in making those connections.

PFI facilitates connections by offering in-person events and activities located around the region, and through online formats such as email discussion lists, social media, and recorded events: especially important during the COVID-19 era. Farmer 19 likened this role to a "long-distance coffee shop":

> …people might make changes because of something that they heard about…but if you don't have that constant reinforcement which is what the coffee shop provides for conventional farmers. It's kind of our long distance or network coffee shop. Because man, these guys get together every day and talk over and chew up every farming practice in the neighborhood and PFI kind of provides that opportunity on a broader geographic scale.

Farmer 18 re-iterated the benefits of long-distance networking:

It's like having close friends, but they're 50 miles or 100 miles away from you instead of being just across the road or down the corner two miles away.

The "secret sauce" of PFI

In addition to the role of PFI in a transition to sustainable agriculture, we sought to understand what it was about the PFI network that worked for farmers given the network's uncommon size and prominence. To discover its "secret sauce," we analyzed questions about why they joined PFI, what was the most important part of PFI, the culture of the network, and comparisons of PFI to other networks and farming organizations to which they belong and to other sources of research and information. Several facets of the network that farmers appreciated emerged through thematic analysis of the answers to the posed questions including the diversity of the network, its culture of openness, its non-ideological stance, and its relative autonomy. We discuss each in turn below.

Diversity. The most mentioned aspect of the PFI network, discussed by 60% of farmers in the sample, was the diversity of its membership, both the diversity amongst the members themselves and the diversity of production systems and ways of farming used by the membership. The cultivation of inclusivity, often referred to by network staff and members as the "big tent" philosophy, is a core tenant of the PFI organization (PFI, 2022), and a recognized strategy in organizational management (Shore et al., 2011; Thomas, 2004). PFI founders Dick and Sharon Thompson cultivated diversity since the network's inception by being open to and encouraging of new ideas and enterprises (Rick Exner, 2023, pers. comm). Farmers told us that today, PFI is unique in the involvement of women, a range of ethno-racial groups, younger farmers, small-scale farmers, and farmers engaged in horticulture and specialty production, in addition to conventional corn and soybean growers who tend to be overwhelmingly white, male, and over 55 (PFI, 2020b; USDA NASS, 2017). For example, Farmer 2 explained:

> I appreciate that they are so encouraging for different types of farming operations from flowers to traditional livestock and crops, that they are encouraging to conventional types, but always showing what options might be out there for moving to more sustainable farming. I never get the feeling that they look down on [anyone].

Farmer 12 discussed their appreciation for the exposure to growers farming different things through their involvement in the network:

> There's just this wide diversity of members. That part really interests me because I'm in an area where it's corn and soybeans, and that's it. There's really no livestock. There's really no diversity. That's helped me too, to know that there is another world out there with these people that are doing all kinds of specialty [crops]. I'm going to call them specialty crops or vegetables or pasture pork or things like that. Farm raised eggs. That's probably the part I enjoy the most is just seeing all this diversity.

Farmer 16 said that this diversity helped them to become more accepting of other ways of farming:

> I think, probably, they've helped me to become more tolerant...Before joining PFI and attending some of their meetings…I thought farmers were corn, soybeans, hogs, and cattle. But it's also raising flowers, and pumpkins, and whatever else…On a five-acre farm, or a 10-acre farm. It's helped me be more tolerant and understanding of some of those other things.

Autonomy. When we asked farmers about their most trusted sources of information, and to compare PFI information and research to other sources, 60% of them discussed their appreciation for the autonomous, independent functioning of the organization. In loosely organized farmer networks, an autonomous nature makes them valuable for their ability to self-organize with little to no institutional funding and for their relative independence from the influence of universities, government agencies, and corporations. Indeed in Hassanein's (1999, p. 75) study of the Ocooch Grazers Network in Wisconsin, network leaders strived to stay "independent of typical university control" to maintain credibility amongst grazers who bore distrust towards the University of Wisconsin. This self-production of agricultural knowledge, a core function of farmer networks, is inherently connected to farmer agency (Dolinska & d'Aquino, 2016), lessening reliance on knowledge generation from public institutions or the private sector.

While some more formalized farmer networks are coordinated through extension or affiliated with a university, PFI is a grassroots, farmer-led organization with strong connections to a diversity of institutions. PFI maintains relationships with ISU as a partner in research trials, workshops, and trainings and works with other conservation professionals, governmental agencies, corporations, and non-profit organizations in different capacities.

To most farmers in the sample, this autonomy meant that the research and information coming out of PFI is less influenced by funding and therefore less biased and more trustworthy. Farmer 15 told us that they did not feel like PFI was trying to sell them anything:

> I mean, they feel more grassroots, they feel more member supported…they may have financial backers, but I don't feel like I'm bombarded by their messaging when I'm trying to access their content.

Many farmers expressed their concern for the validity of university research that was funded by "big ag." According to Farmer 12:

> PFI just comes across as, these are regular people trying to learn something. I don't know that there's an agenda and I don't know if there's an agenda at the universities, but I get a feeling that there might be because they need to raise funding. If you're testing a product at the university

setting, can you be completely unbiased? That's the part I'm just not sure of anymore because they're trying to raise funding all the time. If a company is willing to support an ag program somewhere, I don't know if an ag school is going to say that much bad about their product. Because there's a conflict there, more so probably than ever at a university setting, where I don't get that [at] PFI. I don't know that there's a conflict. [PFI] just always seem like they are people trying to learn what will work for them.

Others specifically had concerns about the influence of funding on the type of research universities conduct. Farmer 6 summed this up by the following:

> I think the [university] research is more funded by funding sources that are commodity agriculture. And as a result, their research is along the lines where they have the interest in... And it's the whole commercial agriculture industry based on that: use herbicide, use this insecticide, use this hybrid, use this tool, this machine or tillage tool.

These remarks highlight that, while PFI does receive funding from private foundations and companies, many farmers in the network believe that the research and information coming out of PFI is relatively less influenced by outside funding compared to universities. As a result of ties to funders, universities are more constricted in their research topics, as explained by Farmer 1: "Iowa State, they're kind of tied to a lot of their donors and they probably do research more in line with what they're doing."

As an additional advantage of PFI, almost half (48%) of the farmers we spoke with said that PFI's on-farm research is more cutting edge. This point was articulated by Farmer 25:

> It's a lot more trying to look at bigger picture stuff where I think some of the Iowa State Extension Research is more sort of focused on business as usual.

A handful of others attributed the innovative nature of PFI's research program as a result of working outside of the constraints of a university system that requires more caution in reporting results. Farmer 17 explained this as:

> Some of the universities, just because of their structure and the need to be kind of overly cautious, aren't always horribly innovative. Their caution stops them from being innovative. They have to be sure the information is a hundred percent correct before they release it. It has to be non-biased and all those kind of things. So it seems like it isn't always the most cutting edge, versus farmers that are just out there pushing the envelope can really come up with some interesting stuff that's right over the edge...Well, they're both very valid, and they have a tendency to be a little bit different, though.

Many farmers echoed a similar sentiment mentioned by Farmer 17 above that they saw both sources of information—university and PFI—as useful. Farmers use and appreciate a diversity of information sources from universities to nonprofits like PFI to crop consultants and input dealers (Šūmane et al., 2018) and our research on PFI farmers shows the same. Over half of the farmers interviewed said that each source of information has its place, and is used for different purposes (i.e., more progressive practices from PFI and more conventional ones from ISU). Farmers also expressed appreciation for research from universities like ISU for their scientific rigor and peer review process while at the same time appreciating the autonomy of PFI as well as the understandable format and ease of access to its information that had been trialed by other farmers "with skin in the game."

The two entities—PFI and universities—were also discussed as complimentary entities with benefits to a continued partnership. "…That's how to get to the conventional farmers.…if something has ISU's stamp of approval on it, then they're going to go for it. They'll at least look at it rather than if it's just PFI", Farmer 19 told us. Farmer 25 related that "[ISU extension has] a lot of agency and a lot of trust for a lot of people in the farm community. And then PFI, they're just reaching, to me, a little bit of a different network. So, I think that there's some integrity to both of those institutions and they could kind of benefit each other." Two farmers explained dual ways in which they saw the two groups working together. Farmer 21 said: "PFI's research provides a springboard for where more vigorous research should be done" while Farmer 17 said that PFI can test university innovation at a larger scale: "[Innovation] has to start some place, so [PFI farmers] see a potential example on a university trial farm and say, 'This is something we should try,' that's a good starting place".

Openness. Thirty-six percent of farmers in the sample talked about the importance of the honesty and vulnerability of other farmers in openly sharing their experiences and ideas. The PFI members Bell (2004) engaged with during an ethnographic study of the network described the guardedness of many Iowa farmers as a result of the public visibility of farming and competition for land. In contrast, Bell found that PFI farmers cultivated knowledge through openness with one another and a willingness to share mistakes, which is fostered by a non-judgmental culture. The farmers we spoke with mirrored this sentiment, explaining that PFI has developed a culture of "no secrets" that defies the current status quo of competition between farmers, and instead encourages cooperation through learning from other's successes and failures. "We're trying to help each other, not hinder each other," said Farmer 18. Farmer 13 explained that:

> You don't feel like you're in competition or that you're trying to steal secrets from [network farmers] or something. They're not afraid to talk about what works and what doesn't…you can share ideas without being laughed at.

Farmer 5 compared PFI to mainstream farming culture, explaining that:

> One of the biggest things I can say about PFI is, everyone will talk. No one has any secrets. This commercial farming, everyone would be so tight lipped about what they say, and [it's ironic] because they're not doing it any different than anyone else. It's kind of frustrating because the way farming used to be in Iowa was, there was four farms on a section of ground, and they'd come over and help the neighbor bale hay, and this and that. And it's just, it's not like that anymore. Everyone's cutthroat…

In this current context of competition and masculinized farming culture (Bell, 2004; Campbell et al., 2006), the willingness to share failures is particularly unique. Status quo culture mandates that farmers, overwhelmingly male in the Corn Belt, are always right and show their best face to maintain appearances. In contrast, Farmer 15 noted:

> Members of [PFI] are willing to try things, willing to fail and willing to share their story. And that's huge. That's really helpful for those that are also learning alongside them...

Farmer 2 concluded that seeing people's successes and failures "has encouraged us to keep moving forward or held us back from making a similar mistake to someone else." Farmer 20 told us it is "the spirit that really has touched me and why I continue to participate."

Non-ideological. One of the ways PFI supports diversity within its membership, discussed above, is by refraining from taking a strong ideological stance on food and farming. Instead, the organization focuses on welcoming all farmers into a "big tent" (Rose, 2021). Almost 30% of farmers in the sample talked to us about the non-ideological and apolitical nature of the organization. In their description of the origins of PFI, Lighthall and Roberts (1995) describe PFI as having "adopted a quiet, non-ideological promotion of the [ridge tilling] system's inherent strengths" (Lighthall and

Roberts, 1995, p. 330). In fact, its founders used the word "practical" in the name as opposed to organic or biological due to its pragmatic and non-ideological nature —using principles of sustainability and conservation, PFI generates "practical" knowledge for farmers (Bell, 2004; Warner, 2007; Rossman, 1994). Leaders of the Ocooch Grazer's network (Hassanein 1999) had a similar rationale in their decision not to98 align themselves with the broader sustainable agriculture movement at the time: "The loosely organized structure and the very specific and limited purpose of the network seemed to make it easier for members to tolerate different views of sustainable agriculture. In other words, because the group did not try to influence government policy and engaged in few outreach activities, they had no major decisions to make and thus potential conflict with respect to explicit allegiance to sustainable agriculture was minimized" (Hassanein, 1999 p. 121).

For PFI, using sustainability as a core principle allows them to find the most common ground across farmers and retain a diverse group of members. One of PFI's founders, Dick Thompson, memorably articulated PFI's strategy as "get along but don't go along" (Carlson, 2021). PFI's Executive Director explained this strategy in a recent annual report: "We don't try to force our beliefs on each other. Rather, we openly share our knowledge and experiences as we work toward PFI's vision. At Practical Farmers, we celebrate our differences and find that we share so much common ground" (PFI, 2020a, p. 5). Farmer 2 echoed this sentiment:

> I think PFI has been pretty good about keeping social issues out. And I really appreciate that…that we can all unite about what we do agree on, and that's sustainable agriculture and sharing information that way, and that we can unite around that common thing and not necessarily have to agree on other points that are going on in the culture and whatever.

In a primarily conservative region, PFI strives to maintain its conventional membership by refraining from espousing what may be considered "liberal" environmental values.

While members may not agree on issues of politics and climate change, a news article on PFI suggests that PFI members "are thinking beyond politicized climate change arguments to figure out solutions" (Freehill-Maye, 2019). Two farmers we interviewed aptly described PFI's non-ideological position:

> Farmer 6: I think PFI has got to be careful not to be too far to the left, and they certainly support sustainability, but they have other PFI members that are conventional farmers, too, that are interested in experimenting around, trying new things with conventional farming, where the goal again is yield bushels of corn, and bushels of beans, or bushels of oats produced. So, I think PFI does a reasonably good job of accommodating both types of people.
>
> Farmer 24: They don't brand themselves as an environmental organization. Yes, in terms of their policy and procedure that they would like to see enacted in farms, I would say they are a pretty forward environmental organization. But in the ways that they advertise, it's a very low barrier to get over, to be like, "Oh, I agree with that." It's gentle. It's nice.

Another way that PFI stays within its non-ideological strategy is by remaining apolitical. The organization does take stances in support of Farm Bill policies that promote conservation and support to beginning farmers and sustainable agriculture research, but it does not endorse candidates nor engage in political debates like other farming organizations such as the Farm Bureau and the Iowa Farmers Union (PFI, 2023b). Farmer 21 noted that keeping divisive politics out was long-term strategy:

> It's a good calculation for their organization because if they were more political, I think they'd be more centrist, which won't play well with the big farmers that are really conservative because

> those conservative farmers would see them as a really left leaning organization. And I think that's something that PFI is really sensitive to because if you've ever gone to any of their conferences or anything like that, something they balance is that they are a big tent at PFI....if they made things more political…I think they'd lose a lot of those farmers…Them just being consistent and offering a lot of research and valuable resources to farmers is the slow and steady way to win the race I guess.

Remaining non-ideological in the overwhelmingly conservative rural Corn Belt, however, is not easy and several farmers told us that PFI already has a reputation in conservative Iowa farming communities as being different, despite their efforts to the contrary. Farmer 16 disclosed:
PFI has a little bit of the reputation as being out there. Whether it's organic, or horticulture, or whatever. Some of the credibility I think, with the corn and soybean grower, is…lessened because of that.

Challenges in the network moving forward

As humans, our personal network tends to be populated with people who are like ourselves, a concept known as "homophily" (McPherson et al., 2001). In the adoption of innovation literature, it is generally understood that the organic exchange of ideas and knowledge is most likely to occur, and is most effective between, individuals within one's own personal network: individuals who are similar to each other in terms of physical, social, and/or economic proximity (Cheng, 2021; Rogers, 2003). PFI farmers likely share similarities as early adopters of conservation practices, yet, surprisingly, PFI runs counter to the concept of homophily in their role of connecting a broader range of farmers. We find that PFI farmers appreciated the cross pollination of ideas from different types of farmers and farmers in different geographical areas to themselves. In this way, PFI is helping spread innovations within a group that is more heterogeneous than the theory would predict. However, through our interviews it became clear that tradeoffs and challenges exist in connecting such a broad range of farmers.

Network diversity. According to farmers, PFI is unique in its diversity of membership that crosses types of farming practices (conventional and organic, large and small scale) and types of farmers (race, gender, age), and in the explicit recognition of inclusivity within its values and goals (PFI, 2023a; Worley, 2021). While PFI does not collect socio-demographic data from membership, their leadership includes women, farmers of color, and represents non-heteronormative sexual orientations (Wilhelm, 2023; Wheeler, 2022) and they offer programming and resources in various languages (PFI 2022), which is uncommon for farmer organizations in the area (Jordan, 2022). Through its "big tent" philosophy, PFI plays a valuable role in expanding the network of its members. The network exposes corn and soybean farmers to other ways of farming, and as a result has broadened the definition of farming for many in the network. Mainstreaming practices beyond "corn and beans" as legitimate and changing the idea of what it means to farm is necessary to achieve a more resilient, diversified agriculture in the Midwest that includes a range of fruit, vegetable, and animal operations in addition to cash grain.

Yet, while the majority of corn and soybean farmers we interviewed expressly appreciated the diversity of types of farmers and types of farming within the network, there was a sentiment among many of those same people that some of the programming was less useful to them and that they wished the network would focus more on practices and issues relevant to themselves. Farmer 14 said, "I will admit that a lot of times some of the smaller scale stuff I'm not as interested in. I wish it was a little more tailored to the large-scale, conventional agriculture and figuring out how to make some of that work. But yeah, I mean, they're diverse in what they're doing, so that's good."

Farmer 19 suggested that the diversity may dissuade conventional farmers from joining: "PFI, I think, is a big tent but conventional farmers don't know about it yet or they're afraid of it…they don't understand that there are conventional farmers in PFI". Farmer 21 captured the dual and at times competing interests in their discussion of less conventionally minded farmers: "A row crop farmer would be like, 'Yeah, that person is not making money in what they're doing. I don't need to hear what they're saying.' So, PFI has to balance that. They value those members, but they also value that member that has 5,000 acres of corn." In other words, PFI balances its desire for diversity and inclusivity while still serving the needs of its conventional farming members.

Network geography. In addition to cross pollination of ideas and information across a diversity of farmers, the network facilitates cross pollination geographically through their role as a "long-distance coffee shop." Applying Granovetter's theory of the strength of weak ties (1973), linking farmers on the periphery to a communication network is critical to the wider diffusion of influence and information. Trauger (2009) explains that the Vermont Women's Agricultural Network performs a similar role by transcending geographic space to connect isolated farmers across vast rural areas. This cross pollination is important given that there are relatively few farmers using conservation practices making the robust exchange of ideas at a local level difficult or impossible.

While connecting like-minded farmers across distances is critical, varied growing conditions and a lack of intimate connections makes it difficult. While some research has shown that more intentional networking can be more effective than physical proximity alone (Liverpool-Tasie and Winter-Nelson, 2012), it is generally thought that learning from individuals in different areas can inhibit social learning due to the inability to compare across conditions (Munshi, 2004; Raz, 2020). Moreover, building relationships between farmers further away is difficult, and the trust cultivated in those relationships is a critical component to the adoption of a new practice (Rogers, 2003;

Granovetter, 2005). Farmer 6 lamented about how little they know about their fellow PFI farmers "…because there's still fewer farmers now, there's just fewer opportunities, and…our social network [used to be] our neighbors four miles away. Today, with PFI, somebody 150 miles away, in northeast Iowa, or it could be somebody in Wisconsin, too, that I may not see very often, once a year, and it's a different type of connection. It's not social. I don't know if they like watermelon after their meal you know? I don't know if their wife makes great gravy and stuff. You know?" Despite these challenges, the reality of farm consolidation weighs heavily and when asked if they would benefit from a network closer to them, most farmers agreed. However, they also expressed doubt that enough like-minded farmers would populate a more localized network.

Going forward, the organization faces complex decisions regarding the extent to which it will focus on its core constituency — corn and soybean farmers, the dominant group on the landscape and those with the greatest environmental impact — or spread its efforts across a diversity of farmers, and how to build trust and communication across farmers located in different areas with varying farming conditions.

5. Discussion

PFI is an independent source of localized, farmer-led research and is relatively unique amongst networks in the US in terms of its size and programming. This research unpacks the role that farmers see PFI playing in their lives and the aspects of the network that make it effective. While much research on farmer networks and networks as a whole has focused on their role in the creation and transfer of knowledge (Hassanein and Kloppenburg, 1995; Hassanein, 1999; Rogers, 2003; Lubell et al., 2014; Hoffman et al., 2015), we find that the PFI network supports multiple functions: to generate and share information on sustainable agriculture, to provide support from a community of like-minded farmers, to connect farmers across long distances, and to serve as a catalyst for change in the region.

Farmer networks, many born out of a need for alternatives to industrial agriculture, were, as Hassenein notes in one of the first in-depth studies of these networks, developed with a "primary purpose to generate and exchange knowledge" (Hassanein, 1999 p. 29). Since then, alternative farmer networks have been shown to generate context-specific knowledge that is relevant to and trusted by fellow farmers (Holt-Giménez, 2006; Bell 2004; Blesh and Wolf, 2014; Kroma, 2006). PFI farmers told us that the experience and ideas shared within the network was one of its core roles, and that its staff is able to distill this in ways that are accessible and easy to understand.

Knowledge alone, however, is not enough to change behaviors that defy dominant ways of production. As described by theories in human behavior change, social conditions are a key driver of human decision making, influencing our beliefs, and instilling an expectation from those around us (Bandura, 1977; Ajzen, 1991; Fishbein and Ajzen, 2010). In the process of exchanging knowledge, PFI generates another key function to adoption: social support. While not as frequently listed as generating and sharing information, our results show that social support to try new practices gained from network participation is an important role PFI plays for its farmers. These findings are in line with an existing study of the PFI network that found that social ties within the network, particularly building relationships, were important to whether a farmer reported adopting conservation practices as a result of their involvement in PFI ([Authors], 2023). The social support function of the PFI network and strength of community that farmers related to us in interviews are characteristics also shared within the literature examining sustainable farming networks. Bressler et al. (2021), Krome (2006), Bell (2004), Hassanein and Kloppenburg (1995), and Hassanein (1999) all find that the networks they studied (Cover Crop Champions program, loosely bound organic farmer networks, PFI, Ocooch Grazers Network, and Wisconsin Women's Sustainable Farming Network, respectively) functioned as a source of social support in addition to a source of localized information. Members appreciated the feeling of comradery created by being around other farmers also considered to be the odd person out. Wypler (2019) described queer and lesbian farming networks that provided access to "human resources" for support, information, and income opportunities. The support function served by these networks is especially important given the limited number of farmers currently using conservation practices in the US, which often means their adoption is an isolating act.

PFI facilitates this support function through both in-person and remote ways of connecting. The coffee shop has long served as an institution in rural agricultural communities for exchanging advice and experience. With large distances between farmers, especially unconventional farmers, PFI helps to facilitate a long-distance coffee shop through its networking activities. In doing so, it ties in a wider range of farmers, although differing agroecological conditions and a lack of face-to-face connection can make it a challenge to diffuse relevant information.

Taken together, PFI farmers see the network as presenting and catalyzing a different way of farming in an area where industrial agriculture is deeply embedded into the values and practices of most farmers. Member farmers encourage each other to think outside the box of conventional farming and identify ecologically and economically sustainable solutions to the issues they face on their farms.

Inductive analysis of the interviews also identified the PFI network's "secret sauce," a recipe of organizational principles that varied somewhat across farmers interviewed but had several key ingredients in common: a culture of openness, a diverse membership, a non-ideological nature, and an autonomous functioning. PFI helps farmers defy a competition mindset of modern agriculture by cultivating a culture of open and non-judgmental sharing of both successes *and* failures. It encourages inclusivity of all farmers, and leaves ideology and politics out of the recipe to support a diversity of membership. In doing so, PFI provides a space for alternative farmer identities and different definitions of farming to exist and thrive amongst each other. Still, while farmers appreciated the "big tent" nature of the organization, the emphasis on diversity and inclusivity requires balancing programming and support for alternative crops with those for the dominant crops on the landscape — corn and soybeans.

In the 1980s, PFI led the first example of a formalized collaboration between an independent farmer network and a land-grant university. Today, PFI's autonomous functioning allows it to continue its strong ties to universities and other organizations, while maintaining enough independence to research more innovative practices and gain the benefits of being seen as separate from the university system.

Together, the roles and the important facets of the network identified by farmers in our sample suggest that PFI operationalizes the key elements of what Röling (1996) identifies as an interactive agricultural science. Interactive agricultural science is centered on a constructivist epistemology, in which innovation is created across a diversity of actors with multiple, and at times conflictual, perspectives and goals. PFI employs participatory practices to build solutions to agricultural problems together with farmers and formal experts and within a spirit of openness, honesty, and inclusivity by finding common ground in the pursuit of sustainability. For these solutions to be adopted by farmers, there must be support to stay on the path of conservation, an important role farmers identified PFI as filling alongside the creation and exchange of knowledge. As the benefits of peer-to-peer networking become more understood and farmer networks grow around the world, we hope that the principles arising from this work are applicable to a variety of situations and farmer organizations. More research will be needed to understand how and whether various contexts — biophysical, cultural, economic, and political — change network functioning.

6. Conclusion

Changing social norms around agriculture and mainstreaming sustainable ways of production through grassroots farmer-to-farmer efforts can be an impactful and sustained way to bring about change in agriculture. As funding for public agricultural research can be variable and influenced by donors and state and federal priorities, grassroots networks are a promising solution to generating and diffusing knowledge and information that is farmer driven and disseminated. Yet, we find that PFI acts as more than a source of and means for the diffusion of knowledge. PFI is changing cultural norms around what it means to be a farmer and establishing legitimacy for a new type of "good farmer", one that adheres to a different set of values and beliefs (Burton, 2004). The social support and encouragement to go against the grain, farmers told us, were core functions of PFI that are key to unlocking wider-scale change in agriculture.

PFI is an independent organization that collaborates with a range of actors including universities and for- and not-for-profit organizations. Our findings suggest that farmer networks may benefit from an autonomous status that allows them to engage with other partner institutions while maintaining their independence as an organization. In the same way that university cooperative extension systems maintain ties to and connect with farmers through Farm Bureaus and commodity organizations, cooperative extension's working relationships with farmer networks should be strengthened in places where they are weak or nonexistent. Indeed, allowing more input from sustainability-oriented farmer networks into university-based agricultural research and cooperative extension is a promising direction.

While farmer networks can emerge as a result of exclusionary systems (Wypler, 2019), networks themselves have the potential to be exclusionary and reinforce dominant culture (Petersen-Rockney et al., 2021). While this research does not tackle the question of the extent to which PFI as a network creates and/or mitigates these kinds of exclusionary tendencies, it does show that PFI farmers appreciated values of openness and diversity which are values that can be prioritized by other networks as well to help encourage inclusivity. Moreover, farmer networks in conservative-leaning regions such as the US Midwest might consider non-ideological approaches to messaging to encourage greater participation among farmers. To realize their potential, farmer networks should be at the center of partnerships in the production and dissemination of agricultural research and diffusion of information, and a high funding priority as an impactful way to bring about greater adoption of conservation agriculture.

References

Aguilar, J., Gramig, G.G., Hendrickson, J.R., Archer, D.W., Forcella, F., Liebig, M.A., 2015. Crop Species Diversity Changes in the United States: 1978–2012. PLOS ONE 10, e0136580. https://doi.org/10.1371/journal.pone.0136580

Ajzen, I., 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen, I., Fishbein, M., 1980. Understanding attitudes and predicting social behavior. Prentice-Hall, Englewood Cliffs, N.J.

Altieri, M.A., 1995. Agroecology: the science of sustainable agriculture, 2nd ed. ed. Westview Press; IT Publications, Boulder, Colo. : London.

Arbuckle, J.G., Ferrell, J., 2012. Attitudes Toward Cover Crops in Iowa: Benefits and Barriers. Extension and Outreach Publications.

Asprooth, L., Norton, M., Galt, R., 2023. The adoption of conservation practices in the Corn Belt: the role of one formal farmer network, Practical Farmers of Iowa. Agric Hum Values. https://doi.org/10.1007/s10460-023-10451-5

Bandura, Albert. 1977. Social learning theory. Prentice-Hall Series in Social Learning Theory. A Englewood Cliffs, N.J: Prentice Hall.

Bates, H., and J.G. Arbuckle. 2017. Understanding predictors of nutrient management practice diversity in Midwestern agriculture. The Journal of Extension 55, 48.

Belknap, J., and W.E. Saupe. 1988. Farm family resources and the adoption of no-plow tillage in Southwestern Wisconsin. Review of Agricultural Economics 10, 13–23.

Bell, M.M., 2004. Farming for Us All: Practical Agriculture and the Cultivation of Sustainability. Penn State Press, University Park, PA.

Blesh, J., Galt, R., 2017. Transitions to Agroecological Nutrient Management Practices in the USA Corn Belt: Principles, Applications, and Making the Transition, in: Agroecological Practices for Sustainable Agriculture. pp. 85–126. https://doi.org/10.1142/9781786343062_0004

Blesh, J., Wolf, S.A., 2014. Transitions to agroecological farming systems in the Mississippi River Basin: toward an integrated socioecological analysis. Agric Hum Values 31, 621–635. https://doi.org/10.1007/s10460-014-9517-3
Bonke, V., Musshoff, O., 2020. Understanding German farmer's intention to adopt mixed cropping using the theory of planned behavior. Agron. Sustain. Dev. 40, 48. https://doi.org/10.1007/s13593-020-00653-0
Brasier, K.J., Sachs, C.E., Kiernan, N.E., Trauger, A., Barbercheck, M.E., 2014. Capturing the Multiple and Shifting Identities of Farm Women in the Northeastern United States. Rural Sociology 79, 283–309. https://doi.org/10.1111/ruso.12040
Burton, R.J., 2004. Seeing Through the "Good Farmer's" Eyes: Towards Developing an Understanding of the Social Symbolic Value of "Productivist" Behaviour. Sociologia ruralis 44, 195–215. https://doi.org/10.1111/j.1467-9523.2004.00270.x
Campbell, H., Bell, M., Finney, M., 2006. Country boys: masculinity and rural life, Rural studies series. Pennsylvania State University Press, University Park, Pa.
Carlisle, L., 2016. Factors influencing farmer adoption of soil health practices in the United States: a narrative review. Agroecology and Sustainable Food Systems 40, 583–613. https://doi.org/10.1080/21683565.2016.1156596
Carlisle, L., de Wit, M.M., DeLonge, M.S., Calo, A., Getz, C., Ory, J., Munden-Dixon, K., Galt, R., Melone, B., Knox, R., Iles, A., Press, D., 2019. Securing the future of US agriculture: The case for investing in new entry sustainable farmers. Elementa: Science of the Anthropocene 7. https://doi.org/10.1525/elementa.356
Carlson, S. 2021. Coming together since 1985. Practical Farmers of Iowa. https://practicalfarmers.org/2021/02/coming-together-since-1985/.
Chambers, R., Pacey, A., Thrupp, L.A., 1989. Farmer first: farmer innovation and agricultural research. Intermediate Technology Publications, London.
Chaplin-Kramer, R., O'Rourke, M.E., Blitzer, E.J., Kremen, C., 2011. A meta-analysis of crop pest and natural enemy response to landscape complexity. Ecol Lett 14, 922–932. https://doi.org/10.1111/j.1461-0248.2011.01642.x
Cheng, H.W.J., 2021. Factors Affecting Technological Diffusion Through Social Networks: A Review of the Empirical Evidence. The World Bank Research Observer. https://doi.org/10.1093/wbro/lkab010
Clancy, M., Fuglie, K., Heisey, P., 2016. USDA ERS - U.S. Agricultural R&D in an Era of Falling Public Funding. URL https://www.ers.usda.gov/amber-waves/2016/november/us-agricultural-r-d-in-an-era-of-falling-public-funding/ (accessed 8.24.21).
Corbin, J.M., Strauss, A., 1990. Grounded theory research: Procedures, canons, and evaluative criteria. Qual Sociol 13, 3–21. https://doi.org/10.1007/BF00988593
Coghlan, A.T., Preskill, H., Tzavaras Catsambas, T., 2003. An overview of appreciative inquiry in evaluation. New Directions for Evaluation 2003, 5–22. https://doi.org/10.1002/ev.96
Creswell, J.W., 2018. Qualitative inquiry & research design: choosing among five approaches, Fourth edition. ed. SAGE.
Crosby, E.W., 1986. The Struggle for Existence: The Institutionalization of the Black County Agent System. Agricultural History 60, 123–136.
Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., Sheikh, A., 2011. The case study approach. BMC Medical Research Methodology 11, 100. https://doi.org/10.1186/1471-2288-11-100
Dainese, M., E. A. Martin, M. A. Aizen, M. Albrecht, I. Bartomeus, R. Bommarco, L. G. Carvalheiro, et al. 2019. A global synthesis reveals biodiversity-mediated benefits for crop production. Science advances 5(10): eaax0121. DOI: 10.1126/sciadv.aax012

Dawson, J.C., Goldberger, J.R., 2008. Assessing farmer interest in participatory plant breeding: Who wants to work with scientists? Renewable Agriculture and Food Systems 23, 177–187. https://doi.org/10.1017/S1742170507002141
DeLonge, M., Robbins, T., Basche, A., Haynes-Maslow, L., 2020. The State of Sustainable Agriculture and Agroecology Research and Impacts: Journal of Agriculture, Food Systems, and Community Development 9, 159–184. https://doi.org/10.5304/jafscd.2020.092.009
DeLonge, M.S., Miles, A., Carlisle, L., 2016. Investing in the transition to sustainable agriculture. Environmental Science & Policy 55, 266–273. https://doi.org/10.1016/j.envsci.2015.09.013
Dolinska, A., d'Aquino, P., 2016. Farmers as agents in innovation systems. Empowering farmers for innovation through communities of practice. Agricultural Systems 142, 122–130. https://doi.org/10.1016/j.agsy.2015.11.009
Eells, J.C., Soulis, J., 2013. Do women farmland owners count in agricultural conservation? A review of research on women farmland owners in the United States. Journal of Soil and Water Conservation 68, 121A-123A. https://doi.org/10.2489/jswc.68.5.121A
Fishbein, M., Ajzen, I., 2010. Predicting and Changing Behavior: The Reasoned Action Approach, Predicting and Changing Behavior: The Reasoned Action Approach. https://doi.org/10.4324/9780203838020
Foster, A.D., Rosenzweig, M.R., 1995. Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. Journal of Political Economy 103, 1176–1209. https://doi.org/10.1086/601447
Freehill-Maye, L., 2019. The Way Climate Change Unites Us. YES! Magazine. URL https://www.yesmagazine.org/issue/building-bridges/2019/11/12/the-way-climate-change-unites-us (accessed 7.23.23).
Gosnell, H., Gill, N., Voyer, M., 2019. Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. Global Environmental Change 59, 101965. https://doi.org/10.1016/j.gloenvcha.2019.101965
Granovetter, M., 2005. The Impact of Social Structure on Economic Outcomes. Journal of Economic Perspectives 19, 33–50. https://doi.org/10.1257/0895330053147958
Granovetter, M.S., 1973. The Strength of Weak Ties. American Journal of Sociology 78, 1360–1380.
Gupta, C., Campbel, D., Cole-Weiss, A., 2019. Cooperative Extension can better frame its value by emphasizing policy relationships. California Agriculture 73, 11–18. https://doi.org/10.3733/ca.2018a0040
Hassanein, N., 1999. Changing the Way America Farms: Knowledge and Community in the Sustainable Agriculture Movement. U of Nebraska Press.
Hassanein, N., Kloppenburg, J.R., 1995. Where the Grass Grows Again: Knowledge Exchange in the Sustainable Agriculture Movement. Rural Sociology 60, 721–740. https://doi.org/10.1111/j.1549-0831.1995.tb00603.x
Heimlich, J.E., Ardoin, N.M., 2008. Understanding behavior to understand behavior change: a literature review. Environmental Education Research 14, 215–237. https://doi.org/10.1080/13504620802148881
Hendrickson, M., Howard, P., Miller, E., Constance, D., 2020. The food system: Concentration and its impacts, A Special Report to the Family Farm Action Alliance. https://doi.org/10.13140/RG.2.2.35433.52326
Hersey, M., 2006. Hints and Suggestions to Farmers: George Washington Carver and Rural Conservation in the South. Environmental History 11, 239-268. https://doi.org/10.1093/envhis/11.2.239
Holt-Giménez, E., 2006. Campesino a Campesino: Voices from Latin America's Farmer to Farmer Movement for Sustainable Agriculture. Food First Books.

Iles, A., Marsh, R., 2012. Nurturing Diversified Farming Systems in Industrialized Countries: How Public Policy Can Contribute. Ecology and Society 17, 42. https://doi.org/10.5751/ES-05041-170442

Jones, A.W., 1975. The Role of Tuskegee Institute in the Education of Black Farmers. The Journal of Negro History 60, 252–267. https://doi.org/10.2307/2717374

Jordan, E., 2022. Agriculture boards lack diversity in Iowa, nation. The Gazette. URL https://www.thegazette.com/agriculture/agriculture-boards-lack-diversity-in-iowa-nation/ (accessed 3.7.23).

Kasprzyk, D., Montaño, D.E., FISHBEIN, M., 1998. Application of an Integrated Behavioral Model to Predict Condom Use: A Prospective Study Among High HIV Risk Groups. Journal of applied social psychology 28, 1557–1583. https://doi.org/10.1111/j.1559-1816.1998.tb01690.x

Klöckner, C.A., 2013. A comprehensive model of the psychology of environmental behaviour—A meta-analysis. Global Environmental Change 23, 1028–1038. https://doi.org/10.1016/j.gloenvcha.2013.05.014

Korsching, P.F., C.W. Stofferahn, P.J. Nowak, and D.J. Wagener. 1983. Adopter characteristics and adoption patterns of minimum tillage: Implications for soil conservation programs. Journal of Soil and Water Conservation 38, 428–431. https://doi.org/10.1016/0167-1987(85)90030-3

Kroma, M., 2006. Organic Farmer Networks: Facilitating Learning and Innovation for Sustainable Agriculture. Journal of Sustainable Agriculture 28, 5–28. https://doi.org/10.1300/J064v28n04_03

Lighthall, D.R., Roberts, R.S., 1995. Towards an alternative logic of technological change: Insights from Corn Belt agriculture. Journal of rural studies 11, 319–334. https://doi.org/10.1016/0743-0167(95)00022-F

Liverpool-Tasie, L.S.O., Winter-Nelson, A., 2012. Social Learning and Farm Technology in Ethiopia: Impacts by Technology, Network Type, and Poverty Status. The Journal of Development Studies 48, 1505–1521. https://doi.org/10.1080/00220388.2012.693167

Lubell, M., Niles, M., Hoffman, M., 2014. Extension 3.0: Managing Agricultural Knowledge Systems in the Network Age. Society & Natural Resources 27, 1089–1103. https://doi.org/10.1080/08941920.2014.933496

Lyon, A., Bell, M.M., Gratton, C., Jackson, R., 2011. Farming without a Recipe: Wisconsin Graziers and New Directions for Agricultural Science. Journal of Rural Studies 27, 384–393. https://doi.org/10.1016/j.jrurstud.2011.04.002

McPherson, M., Smith-Lovin, L., Cook, J.M., 2001. Birds of a Feather: Homophily in Social Networks. Annual review of sociology 27, 415–444. https://doi.org/10.1146/annurev.soc.27.1.415

Munshi, K., 2004. Social learning in a heterogeneous population: technology diffusion in the Indian Green Revolution. Journal of Development Economics 73, 185–213. https://doi.org/10.1016/j.jdeveco.2003.03.003

Nelson, K.P., Fuglie, K., 2022. Investment in U.S. Public Agricultural Research and Development Has Fallen by a Third Over Past Two Decades, Lags Major Trade Competitors. Amber Waves.

Pardey, P.G., Chan-Kang, C., Beddow, J.M., Dehmer, S.P., 2015. Long-run and Global R&D Funding Trajectories: The U.S. Farm Bill in a Changing Context. American Journal of Agricultural Economics 97, 1312–1323. https://doi.org/10.1093/ajae/aav035

Patton, M.Q., 2002. Qualitative research and evaluation methods, 3 ed. ed. Sage Publications, Thousand Oaks, Calif.

Petersen-Rockney, M., P. Baur, A. Guzman, S. F. Bender, A. Calo, F. Castillo, K. De Master, et al. 2021. Narrow and brittle or broad and nimble? Comparing adaptive capacity in simplifying and diversifying farming systems. *Frontiers in Sustainable Food Systems* 5(2021): 56. https://doi.org/10.3389/fsufs.2021.564900.
PFI. 2023a. Mission, Vision, Values. Practical Farmers of Iowa. URL https://practicalfarmers.org/about/mission-vision-values/ (accessed 2.22.23).
PFI. 2023b. Programs- Policy. Practical Farmers of Iowa. https://practicalfarmers.org/programs/policy/ (accessed 2.22.23).
PFI. 2022. Broadening our big tent. Practical Farmers of Iowa. URL https://practicalfarmers.org/2022/07/broadening-our-big-tent/ (accessed 2.22.23).
PFI. 2020a. 2020 Annual Report. Practical Farmers of Iowa
PFI. 2020b. 2020 Member survey. Practical Farmers of Iowa.
Prell, C. 2012. *Social network analysis: History, theory & methodology*. Los Angeles; SAGE.
Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P., 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, 520–534. https://doi.org/10.2489/jswc.74.5.520
Ranjan, P., Church, S.P., Arbuckle, J.G., Gramig, B.M., Reeling, C.J., 2020. Conversations with non-choir farmers: Implications for conservation adoption. Report for the Walton Family Foundation.
Raz, I.T., 2020. Learning is Caring: Soil Heterogeneity, Social Learning and the Formation of Close-knit Communities. In Preparation.
Reimer, A., Thompson, A., Prokopy, L.S., Arbuckle, J.G., Genskow, K., Jackson-Smith, D., Lynne, G., McCann, L., Morton, L.W., Nowak, P., 2014. People, place, behavior, and context: A research agenda for expanding our understanding of what motivates farmers' conservation behaviors. Journal of Soil and Water Conservation 69, 57A-61A. https://doi.org/10.2489/jswc.69.2.57A
Roesch-McNally, G.E., Arbuckle, J.G., Tyndall, J.C., 2018. Barriers to implementing climate resilient agricultural strategies: The case of crop diversification in the U.S. Corn Belt. Global Environmental Change 48, 206–215. https://doi.org/10.1016/j.gloenvcha.2017.12.002
Rogers, E.M., 2003. Diffusion of innovations, 5th ed. ed. Free Press, New York.
Rose, J. 2021. Finding our voice. Practical Farmers of Iowa. URL https://practicalfarmers.org/2021/10/finding-our-voice/ (accessed 2.22.23).
Rosmann, R.L., 1994. Farmer initiated on-farm research. American Journal of Alternative Agriculture 9, 34–37. https://doi.org/10.1017/S0889189300005531
Sachs, C.E., 1996. Gendered fields: rural women, agriculture, and environment, Rural studies series of the Rural Sociological Society. WestviewPress, Boulder, Colo.
Sawadgo, W., Plastina, A., 2022. The Invisible Elephant: Disadoption of Conservation Practices in the United States. Choices. 37, 1-13.
Shore, L.M., Randel, A.E., Chung, B.G., Dean, M.A., Holcombe Ehrhart, K., Singh, G., 2011. Inclusion and Diversity in Work Groups: A Review and Model for Future Research. Journal of Management 37, 1262–1289. https://doi.org/10.1177/0149206310385943
Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., Rios, I. des I., Rivera, M., Chebach, T., Ashkenazy, A., 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. Journal of Rural Studies 59, 232–241. https://doi.org/10.1016/j.jrurstud.2017.01.020

Tamburini, G., Bommarco, R., Wanger, T., Kremen, C., Heijden, M., Liebman, M., Hallin, S., 2020. Agricultural diversification promotes multiple ecosystem services without compromising yield. Science Advances 6, eaba1715. https://doi.org/10.1126/sciadv.aba1715
Terry, D.J., Hogg, M.A., White, K.M., 1999. The theory of planned behaviour: self-identity, social identity and group norms. Br J Soc Psychol 38 (Pt 3), 225–244. https://doi.org/10.1348/014466699164149
Thomas, D.A., 2004. Diversity as Strategy. Harvard Business Review.
Trauger, A., 2009. Social agency and networked spatial relations in sustainable agriculture. Area 41, 117–128. https://doi.org/10.1111/j.1475-4762.2008.00866.x
USDA. 2023. U.S. Department of Agriculture, Economic Research Service. Farm Sector Income & Finances: Farm Sector Income Forecast, February 7, 2023.
USDA NASS. 2017. *2017 Census of Agriculture*. Washington, DC: USDA National Agricultural Statistics Service. (accessed 2.18.23). URL https://quickstats.nass.usda.gov/
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, 59–90. https://doi.org/10.1080/13892249485300061
Wang, S.L., 2014. Cooperative Extension System: Trends and Economic Impacts on U.S. Agriculture. Choices 29.
Warner, K., 2007. Agroecology in action: extending alternative agriculture through social networks, Food, health, and the environment. MIT, Cambridge, Mass.
Warner, K.D., 2008. Agroecology as Participatory Science: Emerging Alternatives to Technology Transfer Extension Practice. Science, Technology, & Human Values 33, 754–777. https://doi.org/10.1177/0162243907309851
Welch, R.Y., Behnke, G.D., Davis, A.S., Masiunas, J., Villamil, M.B., 2016. Using cover crops in headlands of organic grain farms: Effects on soil properties, weeds and crop yields. Agriculture, Ecosystems and Environment 216, 322–332. https://doi.org/10.1016/j.agee.2015.10.014
Wheeler, C., 2022. Some of Iowa's queer farmers are taking a different approach to agriculture. Iowa Public Radio. URL https://www.iowapublicradio.org/agriculture/2022-06-30/some-of-iowas-queer-farmers-are-taking-a-different-approach-to-agriculture (accessed 7.23.23).
Wilhelm, E., 2023. Farmers Anna Hankins of Coggon, and Shaffer Ridgeway of Waterloo, join PFI's board of directors; three others re-elected. URL https://practicalfarmers.org/2023/03/farmers-anna-hankins-of-coggon-and-shaffer-ridgeway-of-waterloo-join-pfis-board-of-directors-three-others-re-elected/ (accessed 7.23.23).
Worley 2021. Vision and Action: Our New Strategic Plan. Practical Farmers of Iowa. URL https://practicalfarmers.org/2021/04/vision-and-action-our-new-strategic-plan/ (accessed 2.22.23).
Wypler, J., 2019. Lesbian and Queer Sustainable Farmer Networks in the Midwest. Society & Natural Resources 32, 947–964. https://doi.org/10.1080/08941920.2019.1584834

Chapter 3 Understanding and leveraging farmer diversification to small grains in corn and soybean systems

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Abstract

Incorporating small grains (cereal crops with small kernels such as barley, oats, rye, and wheat) in corn and soybean rotations in the Upper Midwest contributes to regional food systems resilience while improving ecological health and providing economic value to the farmer. Yet, few farmers in the region grow small grains, and simplified production of corn and soybeans dominate the landscape. This research identifies the barriers farmers face to growing small grains and the factors that have helped some to be successful in their small grain operations. We do so through a survey of 406 row crop farmers, and interviews and focus groups with 38 farmers and non-farming agri-food professionals throughout the grain chain in the states of Iowa, Illinois, Minnesota, and Wisconsin. A combination of farmer-reported survey results, correlation network analysis, and findings from focus groups and interviews shows a range of biophysical, structural, and operational factors that influence why farmers do or do not incorporate small grains in their operations. We find that markets, prices, regional growing conditions, and added management are primary barriers to small grain production on row crop farms. Access to equipment, improved small grain varieties, and the timing of planting and harvesting can be both drivers and barriers, depending on the farmer. Cost share programs, livestock, organic certification, the system benefits of small grains, and the synergies between small grains and cover crops are found to be drivers of production. Crop insurance and revenue supports (Price Loss Coverage, Agriculture Risk Coverage, and Marketing Assistance Loan program) for small grains, availability of neighbors growing small grains, availability of technical assistance for small grains, and access to a loan for small grain production were less

important relative to the barriers and drivers listed above. To enable strong agricultural markets and support farmers to produce small grains, it will be important to 1) invest in market development, on- and off-farm infrastructure, and improved varieties; 2) level the playing field with corn and soybeans in terms of subsidies and supply mandates; and 3) leverage the drivers of existing small grain acreage — certified organic production, the integration of crops and livestock, systems thinking, and cover crop use

Keywords: Small grains, diversification, local food, Midwest, adoption

1. Introduction

In the US Upper Midwest, an area dominated by corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr) production, adding small grains to crop rotations provides a unique opportunity to improve the economic and ecological resilience of farms while building local food systems. Increasing research shows that rotating small grains, or cereal crops with small kernels such as barley, oats, rye, and wheat, with corn and soybeans can improve the yields of corn and soybeans and increase combined net returns of the rotation (Bowles et al., 2020; Davis et al., 2012; Gaudin et al., 2015; Janovicek et al., 2021), and at the same time enhance soil health and water quality. These benefits occur through several mechanisms. As cool season crops, small grains increase surface cover and roots in the ground throughout more of the year, improving soil structure (Janovicek et al., 2021) and soil water storage (Basche et al., 2016). Improved soil structure and water storage reduces soil erosion and leaching by increasing nutrient and sediment retention, which in turn reduces nitrogen and phosphorus losses and freshwater toxicity (Hunt et al., 2019, 2017). Farmers' bottom line and the environment also benefit from the natural disruption of cycles of weeds, pests, and diseases that diverse rotations bring by reducing the use of pesticides and herbicides (Rosenzweig et al., 2018).

Beyond improved ecological and agronomic conditions, small grains can diversify income and contribute a local source of grains that have been largely missing from the basket of local foods available to consumers. As a cash crop with the potential to sell into local or regional high-value food-grade markets, small grains incorporated into simplified systems offer greater enterprise resilience in addition to on-farm resilience (Carlisle, 2014). A growing interest in high quality flours and emerging artisanal brewing and distilling sectors are creating a niche market for local and organic grains (Baker and Russell, 2017; Forrest and Wiek, 2021; Halloran, 2015).

Despite their environmental benefits and emerging economic promise, most farmers in the region do not plant small grains, and as of 2022 corn comprised 48% of field crop acres in the Upper Midwestern states of Iowa, Illinois, Minnesota, and Wisconsin (USDA NASS, 2022). The simplified production of corn and soybeans has led to significant social and ecological repercussions including erosion (Thaler et al., 2021), ground and surface water pollution (Rabalais and Turner, 2019), and loss of above- and below-ground biodiversity (Perfecto, 2009; Rosenberg et al., 2019; Vandermeer, 2018).

Integrating small grains into corn and soybean systems is one promising way to improve the diversity and resilience of the Upper Midwestern agricultural landscape. To this end, we use a mixed method approach including survey, interview, and focus group data to understand our research questions: 1) what are the most important factors driving and hindering adoption of small grains? And 2) what opportunities exist to increase future small grains production? The manuscript proceeds as follows. In Section 2 we discuss the history of small grains in the Upper Midwest and the existing literature on drivers of adoption of small grains. In Section 3 we explain the conceptual framework driving the study design and analysis, and in Section 4 we describe the methods used including quantitative and qualitative data collection and analysis. We discuss the combined results and recommendations across all methods in Section 5 and conclude with the implications of the results in Section 6.

2. The decline of small grains in the Upper Midwest

Farms in the Upper Midwest historically grew crops in a rotation of corn, small grains, and hay and raised a range of livestock (Hart, 1986). Over the last century, the combination of the biophysical characteristics of crops, regional growing conditions, research and development, global markets, and state support for the modernization and efficiencies of agriculture propelled US agriculture towards the simplified production of two crops: corn and soybeans (Blesh and Galt, 2017; Friedman and McMichael, 1989; Ilbery and Bowler, 1998). Beginning in the 1930s, technological developments encouraged intensification and specialization through mechanization, synthetic inputs, and improved variety seed (Lighthall and Roberts, 1995; Ward, 1993). As production costs increased, farms grew larger and more specialized to capture greater economies of scale to pay for more expensive equipment and inputs. Synthetic fertilizers and pesticides replaced extended crop rotations traditionally used to maintain soil health and break up cycles of pests, weeds, and disease (Buttel, 2006; Friedman and McMichael, 1989). The availability of synthetic fertilizers also meant that farmers no longer needed livestock manure to maintain soil fertility, spurring, in part, the decoupling of integrated crop and livestock production (Sulc and Tracy, 2007).

The inherent characteristics and versatility of corn and soybeans and regional growing conditions made them the principal crops for specialization (Philpott, 2020; Pollan, 2006). Corn, a high yielding crop adapted to North America, was already the most common crop produced in the region and responded well to nitrogen fertilizer and breeding efforts (Pollan, 2006). Soybeans largely replaced oats in the mid 20th century as a more economical livestock feed and, as a nitrogen-fixing legume, more agronomically suited for a simplified rotation with corn (Lockeretz, 1988). Winter wheat, the most common small grain grown in the region after oats, failed to thrive in the region's humid weather. (Philpott, 2020).

Corn and soybeans became the focus of research, development, and promotion, furthered by policies and investments from the United States Department of Agriculture (USDA) and the federal government. Public and, later, private breeding programs developed varieties of corn and soybeans to be grown as packages with synthetic pesticides and fertilizers (Cochrane, 1993; Fernandez-Cornejo and Just, 2007). The availability of inexpensive fossil-fuel based agrochemicals, the true cost of which was externalized to the environment and society, made the production of corn and soybeans economical (Buttel, 2006). Commodity and conservation programs started during the Great Depression encouraged the large-scale production of a small set of commodities including corn and later soybeans (McGranahan et al., 2013; Ramey, 2014). Furthermore, subsidized global export markets incentivized farmers to increase their production of core US commodities (Buttel, 2006; McGranahan et al., 2013). As production increased, state-sponsored agricultural experiment stations and private industry developed outlets and accompanying processing for corn and soybeans as a range of products including livestock feed, ethanol, oil, sweeteners, and additives (Lockeretz, 1988; Pollan, 2006). The markets and price of corn further surpassed those of other row crops when, in 2005, the US federal government passed the Renewable Fuel Standard. The act mandated that a portion of all motor fuel contain renewable biomass (ethanol), which is most commonly made from corn due to its high carbohydrate content (Johnson et al., 2021; Mosier and Ileleji, 2006).

Geographical concentration in agricultural processing and manufacturing occurred alongside changes in agricultural practices (Hendrickson and James, 2005). Over the last century in the US, grain handling and milling industries consolidated significantly, resulting in the centralization of processing facilities (Hendrickson and James, 2005; Halloran, 2015; Howard, 2016), leaving fewer local buyers for small grains. In the example of wheat, as flour production increased, the number of mills declined from 22,573 in 1870 to 170 in 2010 (Kim et al., 2001; Posner and Hoseney, 2015).

Together, these structural changes made it easier economically and agronomically to grow corn and soybeans in the region and harder to grow other crops. This led to a decline in acres of cropland devoted to other field crops in the Upper Midwest over the last century, most notably small grains (**Figure 3.1**). Oats experienced the greatest loss, with planted acreage in the region falling by 97% from 1929-2022. During the same period, corn acreage grew over 37% and soybean acreage grew fiftyfold. As of 2022, small grains made up 0.7% of total field crop acres planted in the region (USDA NASS, 2022). Production of small grains shifted to more arid areas to the west with a geographically comparative advantage for growing small grains and where corn production is less suitable. In addition to domestic production in the Western and Great Plains states, the US is also a net importer of oats and rye, and imports substantial amounts of wheat and barley (FAO, 2022). Food companies such as Quaker Oats have processing facilities in the Upper Midwest, but buy their product from other regions and countries (Eller, 2017), while other companies have plans to source from the Upper Midwest to meet sustainability goals (Oatly, 2023).

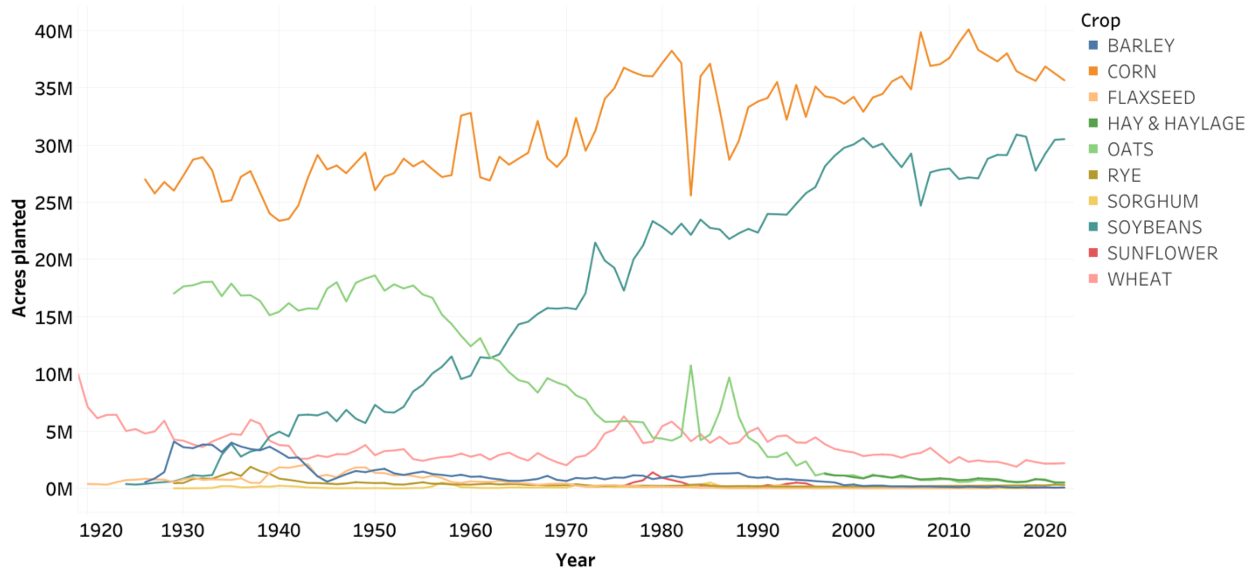

Figure 3.1. Acres planted of major field crops from 1919-2022 in the states of Iowa, Illinois, Wisconsin, Minnesota (USDA NASS, 2022). Beans (dry edible), canola, chickpeas, cotton, hemp, peas, sorghum, and sugar beets were minor crops generally below 500,000 acres planted over this time period and were removed from this graph for readability.

3. Conceptual framework

Applying the concept of constrained choice according to Hendrickson and James (2005), farmers are limited in their abilities to make decisions on their farms that go against current agricultural production practices due to larger structural conditions. Low profits from grain farming require farmers to specialize and grow their operations to take advantage of economies of scale, resulting in higher capital costs and debt loads (Hendrickson and James, 2005). Alongside constant pressure to increase productivity to maintain increasingly high cash rent, these economic pressures "squeeze" farmers, making it difficult to consider alternative production strategies (Buttel, 2006). Farmers are also constrained in the *types* of choices they can make due to existing structures

(Hendrickson and James, 2005). Farmers are limited in their ability to produce alternative crops to corn and soybeans due to lack of technology and equipment to support production and a lack of existing markets and infrastructure including processing and storage (Iles and Marsh, 2012).

Today, most research on expanding small grain production considers field-level management constraints such as yield (Graybosch and James Peterson, 2012), nitrogen availability (Hitz et al., 2017), pests and disease (Ghimire et al., 2020; Jin et al., 2018), weeds (Tautges et al., 2017), and improved varieties (Baker et al., 2020; Sadok et al., 2022; Sandro et al., 2022). In the U.S., only a few studies have explored the barriers and drivers of growing small grains past the farm gate. Baker and Russell (2017) and Muckey (2018) conducted qualitative studies focusing on supply chain development. Baker et al. (2020) surveyed organic barley growers in the US on the primary obstacles to growing the crop, and Weisberger et al. (2021) surveyed Iowa farmers about their perceived barriers and benefits of small grains in extended rotations. Across studies, markets were found to be a key determinant to the production of small grains and collaboration across stakeholders in the supply chain is necessary to improve the market opportunities available to farmers.

Given the importance of external factors that limit farmers' abilities to diversify to small grains, and responding to scholars noting the sparse exploration of the role of structural factors in the adoption of conservation practices (Prokopy et al., 2019), in particular policies and programs (Carlisle, 2016; Fleckenstein et al., 2020), this research makes a focused effort to include factors that can be changed or supported at the policy-level (i.e., Farm Bill policies, markets, technical assistance, publicly funded research priorities). In this way, we add the role of structural factors to existing theories on the importance of psychological drivers of behavior prevalent in adoption literature such as social norms, beliefs, and attitudes (Ajzen 1991; Stern et al., 1999; Fishbein and Ajzen, 2010).

To only examine external, structural factors, however, would be to ignore the complexity of the environment in which farmers make decisions. In this study we include a range of operational, biophysical, and individual factors shown to be important to farmer decision making in addition to political, economic, social factors (Baumgart-Getz et al., 2012; Carlisle, 2016; Prokopy et al., 2019). Building on the limited existing social-science research on the drivers of small grain production, this paper represents the first mixed methods study to attempt to holistically understand farmer decision making around small grains.

4. Methods

This study uses a mixed methods design to triangulate and enrich the ways in which we understand farmer decision making and the factors that impact it. Integrating quantitative and qualitative methods uses their complementary strengths to reach deeper insights into reality (Sayer, 1992). We define small grains as barley (spring and winter), Kernza ®, oats, rye (cereal and hybrid), triticale (spring and winter), spelt, and wheat (spring and winter). The study was collaboratively developed by researchers at the University of California, Davis, Purdue University, the Michael Fields Agricultural Institute, and the Artisan Grain Collaborative (AGC), and guided by a project advisory council made up of farmers and key experts and decision makers in the small grain chain in the region. We focused on the states of Iowa, Illinois, Minnesota, and Wisconsin due to their significant potential for small grains production, and their growing artisan baking, distilling, and brewing sectors. This study received approval for research involving human subjects from the University of California, Davis, Institutional Review Board.

Farmer survey

Data collection

A farmer survey was disseminated between January and April of 2022 during a time when farmers are most available in the region as they have finished harvesting and have yet to begin spring planting. The survey questions were focused on operational details, the barriers to and drivers of growing small grains, the support programs available to farmers, their beliefs about the benefits of small grains in rotations, and the most reliable sources of information regarding small grains. For those who currently grow or have grown small grains in the past, we asked about the kinds of markets and contracts they use for selling their grain, and any infrastructure limitations. The survey was developed in collaboration with the project advisory council and the Farmer Collaborative working group of the AGC (a peer group of farmers supporting food-grade small grain production) and piloted with several other farmers.

We disseminated the survey through several routes. First, we sent the survey to 3,125 farmers through postal mail and email using a stratified randomized sample of farmers purchased from the company DTN, a data analytics and technology company. We disseminated the survey through both postal mail and email to reach a broader population of farmers with varying access to the internet and comfort with email. We limited our sample to those who were farm operators, and to ensure we did not sample hobby farmers, we included corn and or soybean farmers who farmed at least 40 operational acres (as opposed to land leased to others or land in pasture) and farmers growing small grains (those who did not grow corn and or soybeans) who farmed at least 10 operational acres. To ensure equal representation from farmers who had and had not grown small grains, 50% of the sample was composed of farmers who grew corn and/or soybeans and no small grains, 38.5% of farmers who grew corn and or soybean farmers with at least one small grain, and 11.5% of farmers who did not grow corn or soybeans but grew at least one small grain; these categories were constructed based on available farmer profile data from the DTN-provided sample. We targeted corn and soybean farmers due to their large impact on the landscape as the predominant cropping system in the region. However, we also included a proportionally oversampled subset of non-corn and soybean farmers who grew small grains to include a wider range of experiences with small grains, given the small number of farmers who grow them in the Upper Midwest.

We sent out three waves of contact for each route following Dillman (2014) as closely as possible given funding limitations. For postal mail surveys we sent the survey and two follow-up postcards. For the online survey, we sent an email with an invitation to take the survey through the digital survey software Qualtrics, one follow-up email, and one follow-up postcard. After excluding undeliverable addresses and those no longer farming, we received usable postal mail surveys from 219 farmers with a response rate of 25%, and 80 usable online surveys with a response rate of 4%. When excluding the online surveys from the sample, the results were almost identical. For this reason, despite the low response rate, we include these observations to add to the robustness of our results.

Next, after finding few organic small grain farmers in the initial results of the postal mail and email surveys, we sent the survey through two additional online routes: to farmer email addresses from the USDA Organic Integrity database and through the University of Wisconsin Organic Grain Research and Information Network (OGRAIN) listserv, a network of farmers in the Upper Midwest growing organic grains. We collected email addresses from the USDA Organic Integrity database for those farming at least one small grain and sent an email invitation to take the survey, one follow-up email, and one follow-up postcard. We received usable surveys from 41 farmers for a response rate of 14%. In addition, we sent an email through the OGRAIN listserv inviting farmers to take the survey. We received responses from 27 farmers for a response rate of 4% using the number of farmers subscribed to the list. While the response rates are low for the organic-specific routes of dissemination, we believe that they are acceptable given the difficulty of reaching small grain farmers who are also organic. According to the most recent USDA census of agriculture, only 8% of farming operations in the states included in this study grow small grains and only 1% are organic (USDA-NASS, 2017). Our total sample size combining all dissemination routes is 406 farmers.[14]

Analysis

In addition to reporting summary statistics, we used correlational network mapping to explore the factors associated with whether a farmer grows small grains. Correlation network mapping allows us to understand how the independent variables are associated with whether a farmer grows small grains, as well as to understand the statistical direction of the relationships between independent variables. This method also allows us to analyze all relevant independent variables, including those with small sample sizes which lack statistical power to meaningfully analyze in a regression.[15] We chose independent variables based on an iterative process including those that were actionable by the farmer or decision maker in agriculture (see **Section 2**), have been shown to be associated with the use of diversification practices and conservation practices in existing literature, were highly correlated with whether a farmer grows small grains, and through backwards and bidirectional stepwise selection. **Table 3.1** describes the variables used in the correlation network, including the variable name, the original survey question, its quantitative coding, and the sample mean. We use

[14] A conservative sample size calculation showed that we needed at least 384 responses of the estimated 146,326 population of farmers raising corn, soybeans, and/or small grain in the study states for appropriate statistical power using a 95% confidence interval and 5% margin of error.
[15] This was the case for several of the policy variables, for which farmers were less inclined to answer on the survey.

Pearson's correlation in the correlation network to compare coefficients across variables with the same measure of correlation. We tested the robustness of Pearson's correlation with non parametric measures of association fit for nominal variables including Kendall Tau and Spearman's rank correlation and Cramér's V. We conducted additional checks on nominal variables to verify the direction of the statistical relationship through plots and odds ratios. We found similar results across all tests.

Table 3.1. Variables included in the correlation network

Variable name	**Question [Notes]**	**Coding**	**N**	**Mean**
Grows small grains	Which of the following best describes your operation regarding small grains: I have grown small grains as a cash crop or cover crop at some point in the last 6 years; I have not grown small grains in the last 6 years, but have grown them in the past; I have never grown small grains	1 = if yes in the last 6 years; Otherwise, 0	406	0.67
Farmer age	What year were you born? [Age calculated from 2022]	Continuous	375	61
Total acres	Please estimate the acreage of your farmland in 2021: Total acreage (owned + rented/leased)	Continuous	393	671
Percent acres owned	Please estimate the acreage of your farmland in 2021: Acres owned (operated or rented to others) [Percentage calculated from this and above question]	Ranges from 0-1	338	0.65
Livestock on-farm	Did your operation raise livestock, either for sale or for on-farm use in 2021?	1 = yes; 0 = no	395	0.47
Certified organic	*All or some of* my operation was certified organic	1 = yes; 0 = no	405	0.20
No-till/conservation tillage	*All or some of* my operation was farmed using no-till or conservation tillage practices	1 = yes; 0 = no	405	0.50
*Cost share available**	Are/were small grains cost shares or conservation incentive payments (e.g., EQIP or CSP) to grow small grains available to you?	1 = yes; 0 = no	158	0.65
*Crop insurance available**	Are/were small grains cost shares or conservation incentive payments (e.g., EQIP or CSP) to grow small grains available to you?	1 = yes; 0 = For only some of my small grains; 0 = No	196	0.79

Information source: other farmers	Please select the top 3 most reliable information sources regarding small grains: other farmers	1 = yes; 0 = no	371	0.75
Information source: fertilizer, chemical, or seed dealers	Please select the top 3 most reliable information sources regarding small grains: fertilizer, chemical, or seed dealers	1 = yes; 0 = no	371	0.46
Information source: university extension	Please select the top 3 most reliable information sources regarding small grains: university extension	1 = yes; 0 = no	371	0.41
Belief: improves health of soils	Select any of the following statements that you believe are true regarding small grains in rotations: They improve the health of soils	1 = yes; 0 = no	389	0.65
Belief: mitigates risk	Select any of the following statements that you believe are true regarding small grains in rotations: They mitigate risks	1 = yes; 0 = no	389	0.33
Belief: increases yield	Select any of the following statements that you believe are true regarding small grains in rotations: They increase the yields of corn and soybean crops	1 = yes; 0 = no	389	0.44
Belief: reduces chemical needs	Select any of the following statements that you believe are true regarding small grains in rotations: They reduce chemical requirements for pest and disease management	1 = yes; 0 = no	389	0.53

*Note: For both *cost share available* and *crop insurance available,* those who chose "I don't know" were not included. Doing so removes the possibility that the variables become more strongly correlated with *grows small grains* due to the likelihood that those who grow small grains are more knowledgeable regarding whether cost share or crop insurance for small grains is available to them simply because they already grow them.

Focus groups and interviews

Data collection

To gain a more in-depth understanding of the survey results, better understand the causal direction of relationships, explore issues that may not have emerged through surveys, and identify opportunities to overcome barriers and build upon the drivers of adoption, we held a series of focus groups and interviews with farmers and non-farming agri-food professionals from July to September of 2022. Focus groups are a method of data collection that facilitate the development of innovative solutions through the sharing of personal experiences and insights among participants (Bosco and Herman, 2010; Cameron, 2005). For this reason, we used focus groups when possible, and interviews when farmers were not able to join a focus group, or with non-farming agri-food professionals with few peers. While the summer in the Upper Midwest is a time when farmers are more engaged on-farm, we timed the interviews and groups to occur during off periods from planting and spraying across corn, soybean, and small grain production.

Using Martí's (2016) framework for sequentially integrated research designs in participatory research, farmer surveys informed the participant selection and identification of research questions for the focus groups and interviews. Fifteen farmers were recruited based on an indicated interest in participating on the farmer survey. The remaining farmers were recruited through partner organizations to ensure representation from current, discontinued, and non-small grain farmers across all four study states. Non-farming agri-food professionals were purposefully selected to provide expert opinions based on the factors farmers identified as important to their decision making around small grains in the survey.

We created semi-structured interview and focus group protocols tailored to each type of key informant. Using the grounded theory principle that "data collection and analyses are interrelated processes" (Corbin and Strauss, 1990, p. 6), as we gathered responses and formulated hypotheses, we added prompts or questions to test whether the theme was robust across participants. For current small grain farmers, we focused on farmers' experience growing small grains; for discontinued small grain farmers, we focused on why they stopped growing small grains; and for non-small grain farmers, we focused on their thoughts on small grain production. Discussions with farmers began with a general question on barriers and drivers of small grain production, and we then asked specific questions about the common barriers and drivers identified through the farmer survey including markets, infrastructure, government programs, and research and information that could support them to grow small grains.[16] Questions for non-farming agri-food professionals varied based on the sector of the participants, but generally gauged the barriers and opportunities for small grains production in the region and built upon findings from the survey. Thematic memos were completed mid-way and at the end of the period in which we conducted the interview and focus groups to summarize and reflect upon findings as data collection occurred.

A total of 39 individuals participated in 15 in-depth semi-structured interviews and five focus groups, including 22 farmers and 17 non-farming agri-food professionals. Of the participating farmers, fourteen currently grew small grains, five had discontinued, and three never grew small grains. Non-farming agri-food professionals included a crop insurance salesperson, an agricultural lender, a small grain buyer, two small grain brokers, a small grain miller, two Cooperative Extension professionals who work with corn and soybean farmers, five academics researching small grain production, and three advocates working for national and regional NGOs that support small grain production. Interviews and focus groups were conducted either in-person, via Zoom, or by telephone and lasted between 25 to 102 minutes.

Analysis

We used a combined deductive and inductive coding process to analyze qualitative data from focus groups and interviews. An initial codebook was developed with key themes that arose from surveys and the limited literature on the adoption of diversified farming systems (deductive) and key themes identified after reading transcripts (inductive). Further "emergent" themes were added during the process of coding.

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[16]Interview and focus group protocols are available from the first author.

Audio recordings of focus groups and interviews were transcribed using TranscribeMe! transcription service. A total of 1,145 minutes were transcribed. Quality checks on the data were performed when transcripts were unclear and were edited as needed. Data was analyzed in NVivo software (version 1.6.2), and reoccurring themes were identified in farmer transcripts. Non-farming agri-food professional transcripts were analyzed to provide explanation or further detail to themes emerging from farmer transcripts, and to inform recommendations. Key themes were verified by conducting keyword searches of the transcripts. While a key theme did not need to be identified by all farmers in the sample (Deterding and Waters, 2021), we were careful to note negative cases, or instances where a farmer had an opposing viewpoint to the majority (Corbin and Strauss, 1990).

5. Results

Farmers were surveyed from the Upper Midwestern states of Illinois (n=104), Iowa (n=107), Minnesota (n=109), and Wisconsin (m=86). Of the farmers we surveyed, 271 grew small grains as a cash crop or cover crop at some point in the last six years (categorized as "current small grain farmers" for the purposes of this report), 71 grew them in the past but not in the last six years (categorized as "discontinued small grain farmers"), and 64 never grew small grains (categorized as "non-small grain farmers"). The average age of farmers in the survey was 61 years old, the average farm size was 671 acres, and the median farm size was 340 acres. The geographic distribution, age, and average farm size of the sample are representative of the larger corn, soybean, and small grain farming population in these states.[17] The average farmer owned 65% of their land, and 47% of

[17] According to a special tabulation requested through USDA, in the states of Iowa, Illinois, Minnesota, Wisconsin the average farm size of operations producing corn is 602, soybeans is 617, and small grains is 785. The most commonly reported age of farmers producing corn, soybeans, and/or small grains was between 55-64 years.

farmers raised livestock in addition to crops. In terms of farming practices, 20% of farmers were organic or transitioning to organic, and 50% used no-till or some form of conservation tillage[18] (**Table 3.1**).

To understand what determines whether a farmer grows small grains, we used three main methods: 1) what farmers themselves reported as the barriers and drivers through a quantitative survey, 2) the associations found through statistical analysis between individual and farm-level variables and whether a farmer grows small grains, and 3) what farmers discussed as barriers and drivers during qualitative focus groups and interviews. Each method allows us to analyze different but complementary factors in multiple formats to provide a more comprehensive analysis of the determinants of small grains adoption.

Farmer-reported results

According to small grain farmers, economic factors — the price for small grains in their markets, the availability of markets, and the distance to a buyer of the small grains they produce — pose the largest hinderance to their ability or willingness to plant small grains, whether for sale or for on-farm use (**Figure 3.2**). Economic factors, however, can be both a helping and hindering force, and each were about as commonly selected as factors that helped farmers plant small grains (markets 34%; prices 32%; distance to a buyer 29%) as factors that hindered them (markets 33%; prices 36%; distance to a buyer 33%). The factors that farmers selected the most as helping were the timing of

[18] More information on the characteristics of farmers in the sample, the small grains grown, their intended end-use for the grain, the kinds of support programs they use, and how they market their crops can be found in the full report resulting from this research (Asprooth et al., 2023).

planting and harvesting small grains (56%), access to equipment for planting, harvesting, storing, and cleaning small grains (47%), and access to improved small grain varieties relevant to their geographic area or desired markets (36%). The availability of neighbors who also grow small grains and the availability technical assistance or Cooperative Extension specialists for small grains were not commonly listed as either helping (22%; 17% respectively) or hindering (13%; 8% respectively) farmers, suggesting that farmers generally do not see social support from other farmers using similar practices nor access to information and support as a key factor in their decision making around small grains. Still, it is difficult to "know what we do not know" and acknowledge the influence of societal pressures. This finding counters existing literature showing that support from peers (Asprooth et al., 2023; Bell, 2004) can help farmers to transition to practices that defy conventional farming norms, and other research where farmers cite the need for more technical assistance (Weisberger et al., 2021). Our findings may be different given that, unlike other conservation practices, adopting small grains requires displacing a cash crop, making the barriers slightly different.

The policy factors, or those determined by the US Farm Bill, were most commonly selected as neither helping nor hindering or not applicable, although each was more commonly listed as helping farmers (crop insurance 29%; cost share 28%; revenue support 25%; loans 9%) compared to hindering them (crop insurance 11%; cost share 13%; revenue support 15%; loans 7%). Access to crop insurance for small grains, access to cost share or conservation incentive payments for small grains such as the Environmental Quality Incentives Program (EQIP) or Conservation Stewardship Program (CSP), federal revenue support programs for small grains including Price Loss Coverage (PLC), Agriculture Risk Coverage (ARC), and the Marketing Assistance Loan program (MAL), and access to a loan for small grain production were listed as the seventh, eighth, ninth, and twelfth most important factors (out of 12), respectively, that helped farmers to grow small grains.

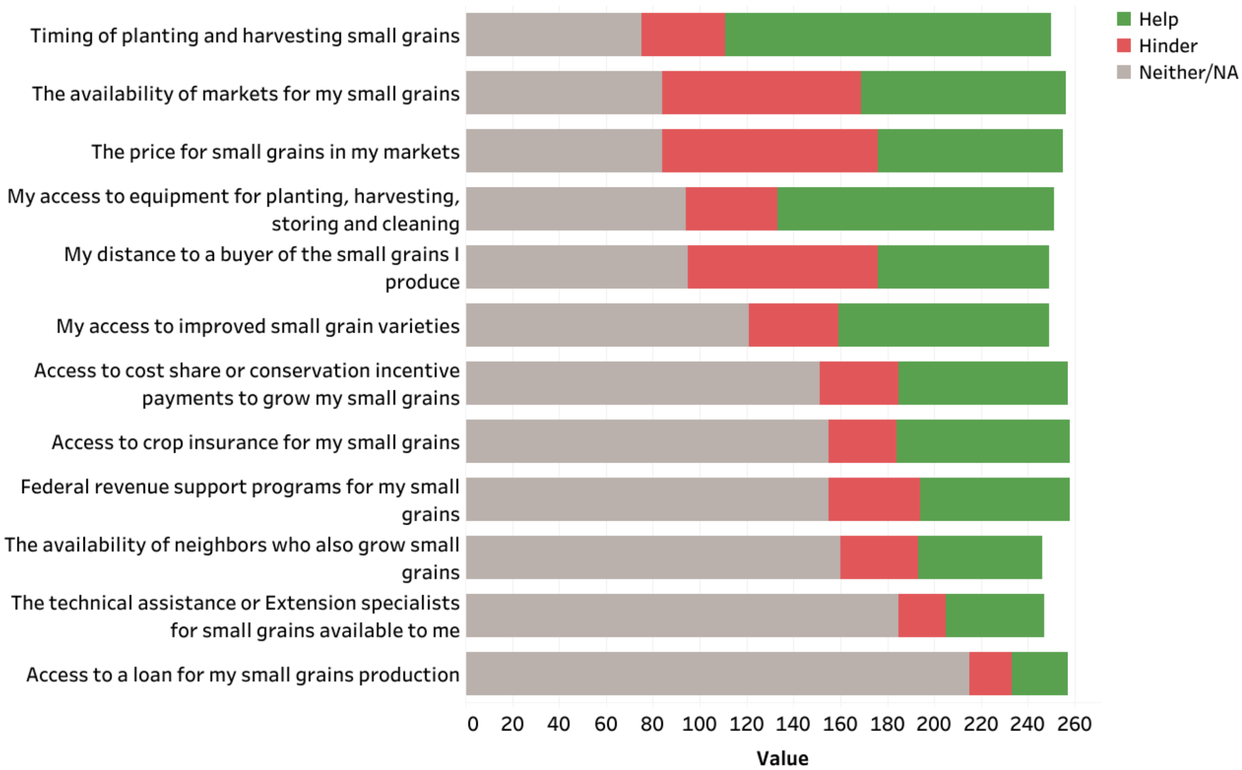

Figure 3.2. Self-reported factors that help or hinder the ability/willingness of current small grain farmers to plant small grains, whether for on-farm use or for sale[19]

Farmers who discontinued their small grain production and those who never grew small grains reported that low market prices (46%) and a lack of markets (43%) for small grains were the most important barriers to production (**Figure 3.3**). Lack of equipment for planting, harvesting, storing, and cleaning (28%), distance to a buyer (24%), and difficulty of timing and planting small grains (21%) were also frequently listed as barriers. "Other" (16%), lack of neighbors growing small grains (15%), and discounts for not making quality specifications (11%) were in the middle of the most important barriers selected. Like current small grain farmers, discontinued and non-small grain farmers did not commonly select lack of federal revenue support programs (7%), cost share (5%),

[19] Results were similar across farmers who grew small grains for sale and those who grew them for on-farm use only

crop insurance (4%), technical assistance (2%), nor access to loans (1%) as barriers to production. Fewer discontinued and non-small grain farmers selected access to improved varieties as a barrier (2%) compared to current small grain farmers (36%).

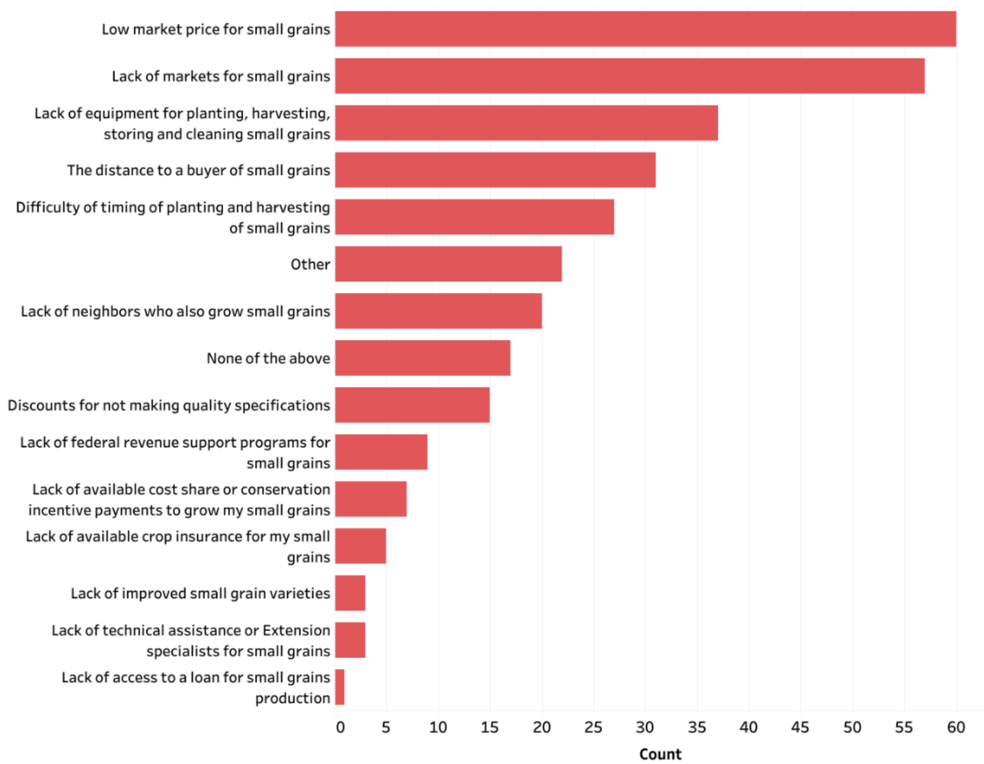

Figure 3.3 Self-reported barriers to small grains production among discontinued and non-small grain farmers
Note: The most common responses in the category "other" were lack of livestock, farmer age, and low profitability.

Correlation network results

Farmer-reported results show that external economic factors such as availability of markets and market prices are important barriers to and drivers of adoption. While markets and prices may vary slightly depending on geographic location, many farmers with equal access to markets and similar available prices make different decisions regarding small grain use. To begin to understand what distinguishes these farmers, we used a correlation network to show the strength of the connections between growing small grains and the individual and farm-level factors that vary across farmers, as well as how the factors are related to each other.

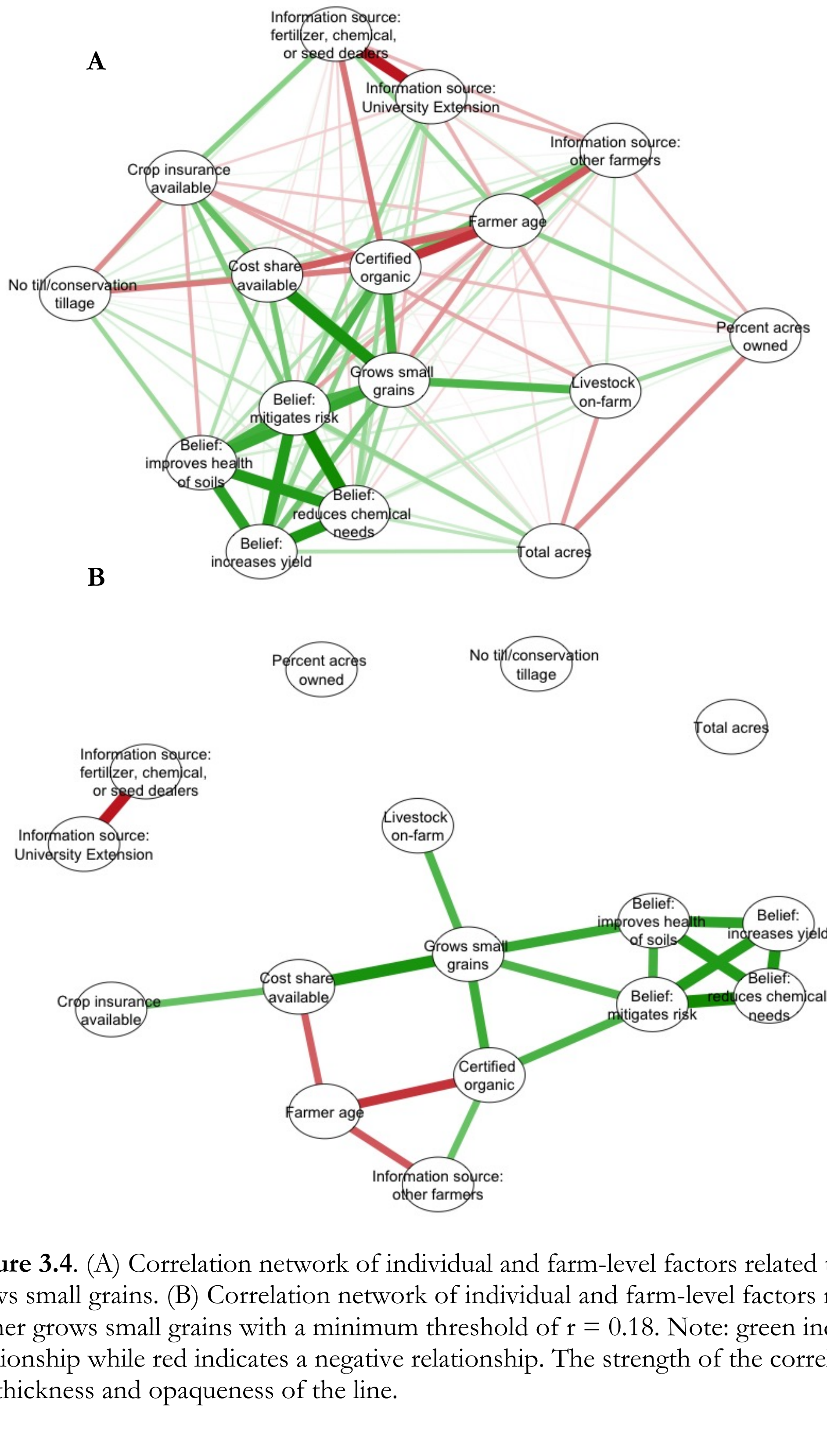

Figure 3.4. (A) Correlation network of individual and farm-level factors related to whether a farmer grows small grains. (B) Correlation network of individual and farm-level factors related to whether a farmer grows small grains with a minimum threshold of r = 0.18. Note: green indicates a positive relationship while red indicates a negative relationship. The strength of the correlation is signified by the thickness and opaqueness of the line.

Figure 3.4 A displays all correlations present across all variables, evidencing the complex interconnection between the factors that can influence farmer decision making around cropping choices. **Figure 3.4 B** shows only the strongest correlations with a threshold of r = 0.18. A threshold of 0.18 was chosen after finding two clear groups ranging from -0.08 to 0.09 and from 0.18 to 0.37, with the latter of the two showing the strongest correlations. We find that the factors most strongly associated with growing small grains are: reporting that cost share or conservation incentive payments (e.g., EQIP, CSP) for planting small grains were available (r = 0.369), believing that small grains in rotations improve the health of soils (r = 0.298), operations that were certified organic (r = 0.283), and operations with livestock for on-farm use or sale (r = 0.244). While a farmers' belief that small grains in rotations improve the health of soils is the belief variable with the strongest correlation with growing small grains, there are also strong correlations between the belief in the soil health benefits of small grains and beliefs that small grains mitigate risks, reduce chemical needs, and increase yields. These interconnections suggest that farmers who grow small grains appreciate them as a system with multiple overlapping benefits. They also support theories on the importance of behavioral beliefs in guiding attitude and intention, and subsequently behavior (Fishbein and Ajzen 2010).

Besides connections between beliefs that small grains mitigate risk and improve the health of soils, there were no strong correlations between the factors strongly correlated with small grain use. Factors that were not strongly associated with growing small grains include the total acres of the farm, the percent of those acres that were owned, use of no-till or conservation tillage, the farmer age, the availability of crop insurance, and the information source where the farmer turns for small grain needs.

Farmer focus groups and interview results

Farmers shared their insights on the benefits to and challenges of growing small grains in the Upper Midwest through focus groups and interviews. Of the 22 farmer participants, 15 currently grew small grains, four had discontinued, and three never grew small grains and grew only corn and soybeans. Overall, participating farmers grew a range of crops including corn, soybeans, small grains, alfalfa, and peas. Four farmers were from Iowa, five from Illinois, six from Minnesota, and seven from Wisconsin. Eight of the farmers were certified organic, and ten raised livestock in addition to crops.

In **Table 3.2** we identify the most common themes that arose from our conversations during interviews and focus groups with farmers, along with an illustrative example quotation. Overall, farmers' perspectives shared in the interview and focus groups focus on similar elements and significant relationships from the survey findings. Farmers re-iterated that price and markets, above all factors, were the largest barriers to the production of small grains in the region. They also echoed the importance of the timing of planting and harvesting small grains, equipment for small grain production, and improved small grain varieties. The presence of livestock, which was correlated with small grain use in our statistical analysis, also emerged as important during our conversations with farmers. Factors that were not listed on the survey, but were central during farmer discussions, were the system benefits of small grains, the synergies between cover crops and small grains, the difficult regional growing conditions, and the additional management needs of small grain production. As in the survey, farmers noted that support programs such as cost share, crop insurance, and revenue support programs did not drive their cropping decisions.

Table 3.2. The most important factors driving decision making around small grain production according to farmer focus groups and interviews

Prominent theme	**Example**
Price	"Unfortunately, I wish we could raise more and make money off it. But, yeah, there's other ways to make a better living farming than to raise wheat in this country."
Markets	"I guess it gets back to the markets, how difficult is it to market your cash crop. Corn and beans, of course, you just run them to wherever, ADM or local elevator or wherever and you get the market price. But with oats, it just wasn't that easy."
Timing	"[What] we run into up here just being wet springs. This year, it was a late year. You usually want to start planting around just say 20th of April. We didn't start anything until the 8th of May. So now all of a sudden, it's a tier like that. You didn't get anything seeded and your corn's not in the ground...It's like, do you want people spending time planting wheat, when all their corn should be getting in the ground. So it's just a complexity of timing issue."
Equipment	"We would have to buy some sort of machine to plant small grains because we don't have a grain drill anymore. At least not a grain drill that's usable. So we would need to invest in that equipment."
Regional growing conditions	"As a grower, you guarantee me the right week of [harvest] weather, and I'll have a whole lot of oats out here. But that just doesn't happen very often."
Improved small grain varieties	"Private investment in breeding stock would be my number one because wheat yields haven't changed comparative to every other commodity out there. I mean take your corn and beans, even sugar beets over the last 20 years. I mean, as a kid, we raised 50, 55-bushel wheat. Today we're raising 60-bushel wheat. And you compare that in beans and corn or even sugar beets where we're at, and it's ridiculous the amount of advancement we've made; there's a stalemate in the wheat product."
Livestock	"The small grain paradigm evaporated when the livestock left farms. Every dairy farm used to grow its oats or barley and go in a rotation like that and now it's the big farms or the dairies and nobody else does it."
System benefits	"It's probably the one thing that keeps me from completely dumping spring wheat or barley or whatever on the farm there is, just there are some benefits to having that, in our case, fourth crop in the rotation. And you can't put a dollar figure on it right now, but there's an advantage to it. So we keep a little bit around for that reason."
Synergies between small grains and cover crops	"I don't have all the solutions, obviously, but I see that farmers know they need small grains. Even our conventional neighbors are planting cover crops. It won't be long to convince them, right? They're already planting rye as a cover. It's kind of getting there."
Additional management	"I mean, there's a few guys who are, 'Yeah, I want the easy.; Easy is corn and soybeans…everything's all set up for it."

6. Discussion and policy implications

Below, we discuss in further detail the key determining factors of whether a farmer grows small grains based on multiple methods (quantitative surveys and qualitative focus groups and interviews) and through multiple ways of knowing (farmer-reported results and correlational network mapping) (**Figure 3.5**). We find that biophysical, structural (social, economic, political), and operational factors

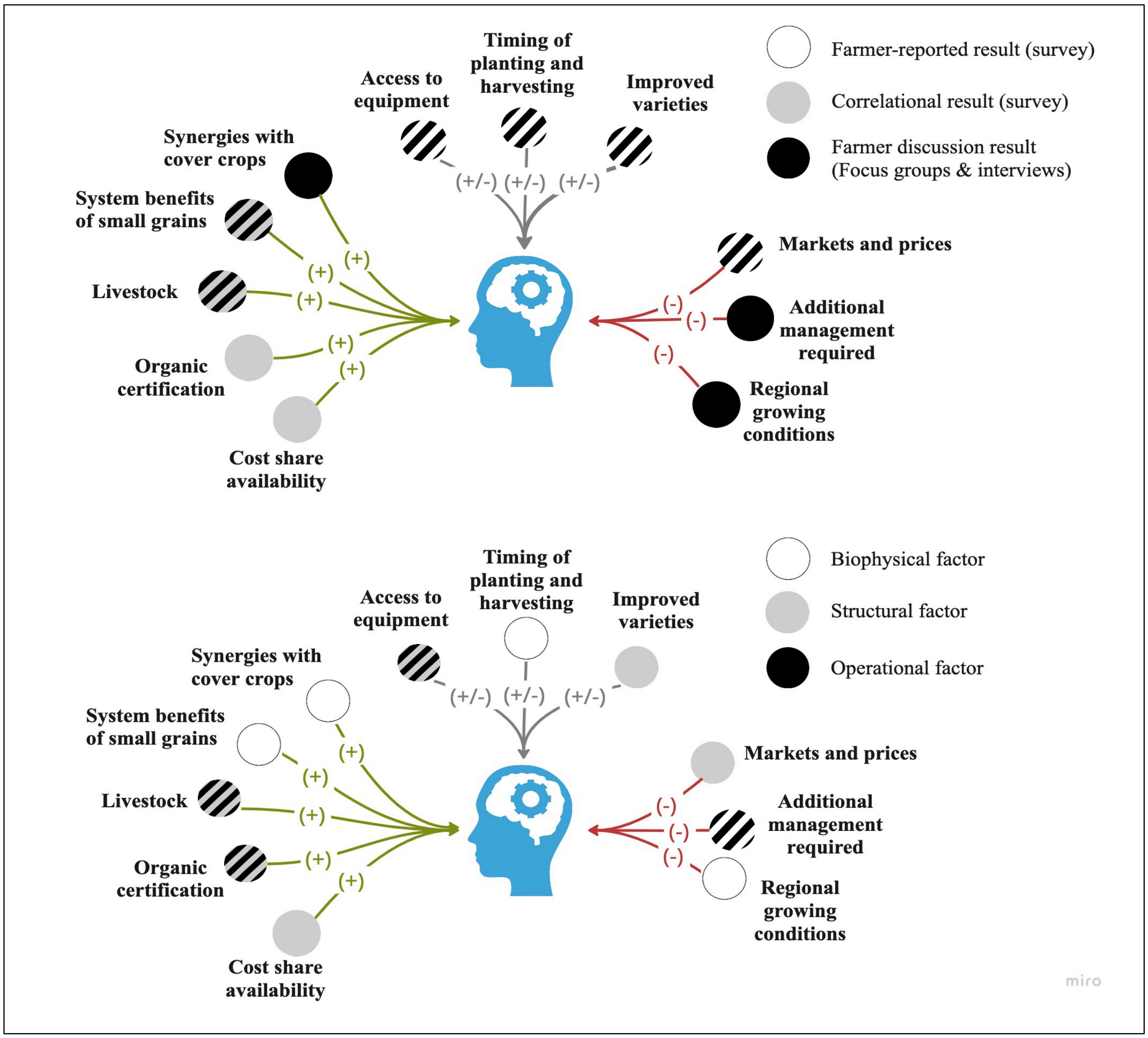

Figure 3.5. **(A)** Determinants of small grain production by method and way of knowing

(B) Determinants of small grain production by type of determinant. Note: shading of circles indicates the method used to determine the result or type of determinant. Striped shading shows multiple methods or types of determinants supporting the same result.

act as both barriers and drivers of farmers' decision making around small grains (**Figure 3.5**). Markets and prices, regional growing conditions, and additional management are the strongest current barriers to small grains production. Access to equipment, improved small grain varieties, and timing of planting and harvesting can be both drivers and barriers to production depending on the farmer. Livestock, cost share programs, the system benefits of small grains, the synergies between small grains and cover crops, and organic certification are found to be drivers of production. Crop insurance and revenue supports (ARC, PLC, MAL) for small grains, access to a loan for small grain production, and technical assistance are not found to be important to a farmers' decision to grow small grains. We include additional summary statistics and results from in-depth interviews and focus groups with non-farming agri-food professionals throughout the grain chain to understand how and why these factors impact small grain production.

Markets and prices. The most frequently noted barriers to growing small grains by farmers in the survey, interview and focus groups across current, discontinued, and non-small grain farmers were structural factors including markets and prices. Specifically, farmers reported that the market price, the availability of markets, and the distance to a buyer were the key barriers to integrating small grains on their operation. Weisberger et al. (2021) and Baker (Condon et al., 2015) also found that markets and prices were the biggest barriers to production among surveyed farmers. During focus groups and interviews there was a resounding sentiment that to grow more small grains, more local markets were needed with higher prices. A current small grain farmer from Iowa told us, "In North Central Iowa, it's corn, soybean country. If we don't have a solid, dependable market, [small grain production] ain't going to happen. The $5 discount on the crop insurance–and they can do a little bit on ARC or PLC or whatever. But it's still not going to work if we don't have a solid market." Farmers explained that while small grains require fewer inputs, making them less expensive to grow, and have the potential to market the straw, the return on investment of corn and soybeans is higher.

Finding local buyers for small grains was also identified as a barrier, as farmers explained that their local elevators no longer buy small grains. A discontinued small grain farmer from Minnesota recounted that he had to haul his wheat over 100 miles to find a buyer "Because otherwise the local elevators won't even take it because it's a pain. Because they're all set up for corn and soybeans and where are you going to put a truckload of wheat?" Many farmers said that the distances required to haul their small grains was too far to make production economical. A current small grain farmer from Illinois explained: "You know, I think if we're going to grow wheat, or we're going to grow barley, whatever we can grow, I think you're going to have to look at a transportation problem…I have to go somewhere at a distance to us. So that's a problem." As a result of market access issues, several farmers we spoke with have had to sell their grains on conventional (if they were organic) or livestock feed markets at a lesser price after failing to find local buyers for their product.

Because small grain buyers are fewer, successful farm-gate sale requires looking beyond the local elevator and, subsequently, requires more time and effort. Despite these challenges, however, farmers saw growing demand for small grains and potential for future small grain markets. Indeed, when asked about customer preference for local grains, one miller we spoke with shared "There's definitely bakers in our region who want to be able to communicate [that the grain/flour is local] to their customer base. So their customer base must be asking. And our bakers then want to be able to communicate the message that it is local." Farmers and non-farming agri-food professionals suggested that building consumer markets by launching and building brands for diverse products and byproducts, supporting more local milling and processing, promoting regionally-grown certifications, and developing farmer marketing coops are key to supporting small grain markets in the region. Policy levers such as tax incentives to both large- and small-scale food companies and processors to source locally grown grain and limiting or taxing small grain imports can stimulate production and encourage latent markets. Additionally, removing the corn ethanol mandate within the Renewable Fuel Standard will likely lower the price of corn (Condon et al., 2015), and at the same time make markets for other crops, such as small grains, more competitive.

Timing. Winter and spring cereals occupy a temporal niche in northern cropping systems, creating both opportunities and challenges for farmers. Timing of planting and harvesting was the most frequently selected factor that small grain farmers said helped them in their small grain operations (56% of the sample), while 20% of non- and discontinued small grain farmers listed it as a barrier to production. During focus groups and interviews, farmers emphasized the importance of a new crop fitting well into their existing systems and explained several ways in which the timing of small grains can be both beneficial and detrimental.

Small grain farmers appreciated the window of time after small grains are harvested that allows for a longer growing season for cover crops. Livestock farmers noted benefits from the longer window of time to spread manure afforded by the earlier harvest of spring planted small grains compared to corn and soybeans. On the other hand, small grain and non-small grain farmers alike were concerned about small grains impacting their ability to tend to their main cash crops — corn and soybeans — especially given the widespread lack of labor.

Farmers also acknowledged that planting small grains in the spring and fall is not always easy given the variable weather conditions in the Upper Midwest. Wet springs, a late corn harvest, and an early frost can mean a small grain crop does not make it in the ground in time. According to a current small grain farmer in Illinois, getting a small grain planted in the fall was, "Great in theory, but we've had some years where we don't get done until it's snowing. So, in a perfect world then we're done by Halloween or first week in November. It'd be fine. But when we get those years where we're not done [with corn harvest] until Thanksgiving or later, then, all of a sudden, it's like, this isn't going to work. So that's probably another really big concern…is just getting the timing of some of that stuff done."

Equipment. Small grains require a different set of equipment to plant, harvest, and clean compared to corn and soybeans. Equipment for small grains was the fourth most selected factor that *helped* small grain farmers' ability or willingness to grow them. At the same time, lack of equipment was selected as the third most limiting factor for non and discontinued small grain farmers, just below markets and prices. This tells us that equipment, if accessible, can be a driving force for the adoption of small grains in the region.

Equipment is both a structural factor in that equipment for small grain production is often outdated and difficult to obtain, and an operational factor in that many farmers no longer have equipment for small grains and/or the financial resources to purchase it. One discontinued small grains farmer from Minnesota explained the issue in the context of existing production systems: "They made the corn — feeding the corn to [livestock] so easy. I mean why would you do something else? Now all of a sudden you need another bin, you need a different planter, you need a different seed." A Wisconsin farmer acknowledged that if he didn't have a nearby neighbor to help clean their wheat, they didn't know where they would take it; "I haven't crossed that bridge, and in that respect then, it would be limited."

Several farmers also suggested that they would grow more small grains if they had more on-farm storage, which allows them to hold onto their product until they find a competitive price. A small grain farmer from Wisconsin explained, "We can't commit to any higher paying or more diversified contracts because we don't really have good storage… If we had more storage on-farm, that would definitely change the game a bit." More support for, and awareness of, programs that support purchases of equipment and on- and off-farm storage such as the Minnesota Department of Agriculture's Soil Health Financial Assistance Grants to purchase or retrofit soil health equipment and the USDA-FSA Farm Storage Facilities Loan Program are needed to help farmers grow and sell a quality product.

Regional growing conditions. Upper Midwestern weather makes growing small grains in the region more difficult to compete with production in the Central Plains, Western US, and Canada. Higher levels of rainfall and humidity impacts the ability of farmers to meet quality requirements specified for milling and malting. During focus groups and interviews, farmers discussed the trouble competing with more arid regions to the West that have fewer issues meeting standards of moisture content (important for proper storage), mycotoxin limits (secondary metabolites produced by molds that are toxic to humans and animals at certain thresholds), falling numbers (amount of pre-harvest sprouting), and test weights (heft of the grain). Because of these issues, farmers were often paid less than they expected for their small grains due to quality discounts, or had loads rejected, making their production a less reliable source of income compared to corn and soybeans — a risk that was often not worthwhile given their lower market prices and distant markets. When asked about what was needed to meet test weights on oats, a common problem for oat farmers, a discontinued small grain farmer from Iowa explained, "Well, that gets into the agronomy department of developing oats, which I think they've worked on quite a bit since I was doing it, I hope. But it's still hard to overcome the climate, the weather, and things. That has a lot to do with it."

Improved small grain varieties. Access to improved small grain varieties relevant to a farmers' geographic region or desired markets was the third most selected factor that *helped* small grain farmers' ability or willingness to grow small grains. Those farmers who have discontinued growing small grains and those who have never grown small grains did not commonly report a lack of improved small grain varieties as a barrier, although focus group and interview data suggest that this is due in part to non-small grain farmers inexperience with small grain varieties. During focus groups and interviews, the issue of genetics came up frequently, and farmers told us that they did not have access to the small grain varieties, especially for organic production, that they need to be profitable.

Modern improved varieties are developed by plant breeders in a process largely external to the farmer, thus we categorize access to them as a structural factor. Improved varieties can help farmers increase yields and manage disease and toxins from mold and fungi such as vomitoxin, fusarium, and aflatoxin that are particularly challenging in the Upper Midwest due to relatively high levels of rainfall and humidity during the growing season. There was a particular focus on the need for varieties suited to the wetter conditions of the region to compete with farmers in the Dakotas and Canada, where much of the small grains are currently grown. A current small grain farmer from Illinois told us: "I think there's profit to be made [in small grains]. We just need to be looking at different varieties…I'm not sure that we've really developed wheat, for our organic side. The problem with the organic side is that you have no rescue, you can't go in with fungicides, you can't go in with the herbicides, you can't go in with anything like that…I'd like to see maybe a little better, a little different breeding program…There needs to be some new characteristics in it. Some new varieties brought out. I mean, we're planting the same oats I did as a kid. You know, 45 years ago."

Due to their limited acres and therefore limited profitability for private investment, small grains in the Upper Midwest are "orphan crops", or crops that receive little attention from the private sector despite their importance to food security, and therefore remain largely in public sector breeding programs (Moore et al., 2023; Naylor et al., 2004). Consequently, many of the more advanced biotechnologies related to plant breeding have not been applied. Public sector plant breeders rely instead on more traditional breeding methods that, while producing less costly seed, can take upwards of 10 years to bring a new line to market (Alahmad et al., 2022; Shelton Janie F. et al., 2014). The small grain breeders we spoke with lamented that funding is lacking for public small grain breeding programs, a global issue among public breeding programs that has resulted in a decline in public plant breeders and public cultivar development (Knight, 2003; Shelton and Tracy, 2017). They explained that more sustained, long-term funding for public plant breeding is needed along with efforts that can speed up the varietal development process at public institutions like the Small Grains Genomic Initiative.

Still, there was a sentiment amongst the breeders that varieties developed in the private sector with advanced breeding technologies tend to be seen as modern or cutting edge by farmers and therefore more desirable. Most small grains, however, naturally require fewer inputs (Marshall et al., 2013). Because small grains are primarily public sector crops, with little to no investment from the private sector, very few examples of genetic modification exist. This makes seeds for these crops generally less expensive, and therefore it is possible that more of the profit goes to the farmer compared to agricultural input companies. This results in a better outcome for farmers' bottom lines. Promoting the low-input and low-cost nature of small grains can help reorient farmers to their inherent benefits compared to corn and soybeans.

Livestock. Results from the correlation network analysis and focus groups and interviews showed that livestock can help drive small grain production. We find that livestock acts as both a structural driver in terms of the availability of livestock markets near the farmer, and as an operational driver in terms of whether the farm chooses to have livestock on-farm. Both are due to the synergies between small grain production and livestock: livestock act as a secondary market for grain that does not find a buyer, and small grain silage and straw provide a source of livestock feed and bedding. In this way, farmers "hedge" with livestock to lower the risk of small grains production.

Food-grade production of small grains in the Upper Midwest is risky due to the difficulties of meeting quality grade specifications required by buyers (see regional growing conditions section). A much higher percentage of farmers in the sample (70%) grew small grains for livestock, either for on-farm feed or bedding, sale as feed, or sale as straw, compared to those who grew for food or beverage grade (38%). Livestock feed markets, on the other hand, have fewer quality requirements and several farmers stated that livestock feed and bedding are the most viable markets in the region. Many of them said that they would be more likely to grow more small grains if they had livestock markets around them or on-farm livestock.

Livestock, however, has spatially concentrated as crop and livestock systems have decoupled in the US (Friedman and McMichael, 1989). Iowa farmers surveyed by Weisberger et al. (2021) reported that the decline in integrated crop-livestock systems was a major barrier to small grain and forage production. Even in areas concentrated with livestock, however, markets for small grains as feed are no longer common. This is likely because, as discussed in focus groups and interviews, farmers consider small grains as slower to fatten an animal and less palatable compared to corn and soybeans, and silage making of small grains involves more risk than corn and soybeans due to the uncertainty of when to harvest to optimize nutrients. A dairy researcher told us, "Corn is the king, and alfalfa is the queen. And that's what it takes to make a kingdom…We've created such specialized, very intricate systems that rely on corn and legumes that complement each other in terms of what they give to the animals that it pushed away other possible feeds."

Yet, replacing a portion of corn with small grains in feed rations can lower the cost of the ration and has been shown to support equivalent growth rates and feed efficiencies (Lammers, 2017; McGhee and Stein, 2021). Echoing Muckey et al. (2018), more research on feed grade opportunities for small grains should be pursued. Promoting small grains in livestock rations and greater small grain varietal development suitable to livestock feed will help improve their potential as a livestock feed. Moreover, reversing geographic concentration of livestock production by re-integrating crop and livestock production on farms throughout the region will be key to providing feed markets for small grains and to encouraging small grain production for on-farm use. Encouraging integrated crop-livestock operations can be achieved through more technical assistance and cost share through programs like EQIP, as well as more research on the benefits of integrated crop-livestock systems.

Cost share programs. Farmers did not commonly report that cost share programs such as EQIP or CSP influenced their decision making; however, correlational network mapping showed that whether a farmer said that cost share for small grains was available to them was strongly correlated with whether they grew them. During focus groups and interviews, farmers explained that while cost share programs do not drive their decision making, some said that the additional incentive helps. A current small grain farmer from Wisconsin explained, "If you got that seed money or that cost sharing or whatever, it definitely helped. Many times, you got to jump through some hoops, but most of the time it's worth jumping through the hoops." Yet, through focus groups and interviews it was clear that cost share programs can be improved to realize their potential on adoption. Farmers explained that the application processes must be simplified, greater flexibility afforded to participants, and more funding is needed to support the programs.

System benefits. A farmers' belief that small grains in rotations improve the health of soils was strongly correlated with growing small grains. Additional strong correlations found between the belief in the soil health benefits of small grains, and the beliefs that small grains mitigate risks, reduce chemical needs, and increase yields re-enforce that farmers understand small grains as a system with multiple benefits. While it is clear that economic considerations are central to whether a farmer grows small grains, to be adopted it is important that a new crop fit well into existing agricultural systems (Lockeretz, 1988). Farmers in the study struggled to make small grains profitable in relation to corn and soybean production, however many said they continue to grow them "on principle" due to their benefits in a rotation. One farmer from Iowa explained that growing small grains is part of his "conservation ethic" to ensure the health of his soils and local waterways. Other farmers discussed the positive impact small grains had on reducing pest and disease pressure and increasing water infiltration.

The benefits to soil health were particularly important to the farmers in our study. Surveyed farmers recognized the soil health benefits of small grains — 46% grew small grains at least in part as a cover crop or green manure, 59% said that the reason why they grew small grains was in part due to the soil health benefits (the most selected reason), and 65% of respondents said that they believed small grains in rotations improve the health of soils. One current small grain farmer from Illinois said: "I've noticed that when I took this farm over seven years ago, they were not doing hardly any small grains. And I have, you know, really stepped in to do it. And I find, I mean, we're doing less tillage. So, you know, especially in today's market and the price of fuel, everything that's got small grains on it, that soil seems to be much, much looser, a much nicer soil, better seed beds. So, I think we're gaining on the corn and soybean end of it also, gaining some production here."

Thus, while stronger markets for small grains will do the most to incentivize their use, promoting their system benefits may also drive production, especially on marginal land. A researcher we spoke with summed up the sentiment: “Clearly small grains have lost ground to corn and soybeans in the last century…if you want to advocate for it you’re not going to get it back into the system by comparing it in one dimension…you need to put it in a whole system context…this is how you are going to get farmers to say, yeah that makes sense.”

Synergies between small grains and cover crops. Through focus groups and interviews, the unique synergies between cover crops and small grains emerged. Cover crops and small grains can feed into each other in ways that support each other’s production. Cover crops act as a gateway to small grain production; once a farmer sees the soil health benefits of a small grain as a cover crop (a crop used to cover otherwise bare soil to reduce erosion, increase organic matter, and suppress weeds; Bruce et al., 2022), and gain some experience growing them, they will be more comfortable taking the leap to feed or food grade production. At the same time, small grains in a rotation can act as a “nurse crop” for cover crops; they are harvested early enough in the season to allow time to establish a fall-planted cover crop. Given that using small grains as a cover crop is the second most common use for small grains listed by farmers on the survey, this may be a promising strategy to encourage small grain production. A current small grain farmer from Wisconsin recounted, “The original times that I grew wheat as a dairy farmer was as a cover crop. FSA was pushing it and basically, we had absolutely no intention of keeping it for a cash crop, it was going to be destroyed in spring, but all of a sudden you had a nice crop out there… Let's see if we can do something with it. And A and B leads to C, and it kind of falls in place.”

Rye and barley are two small grains commonly grown as cover crops in the Upper Midwest, however, there are few buyers for these crops. A small grain broker explained, “There's always a little bit of an oversupply of those two, or lack of a market…It either goes into the feed market and some of it goes into the beverage industry or the food industry, but the vast majority of it's just grown for a cover crop because there's no market to support it really, or very little…I actually just think that there needs to be more market development…it's a little bit more about having a concerted effort then for bench-top development and research and development to really go into play. Rye could be used in a number of different capacities than what it's currently used today."

Organic certification. Small grains are a viable and common way to fulfill the extended crop rotation requirement for organic certification, and being certified organic is strongly correlated with growing small grains. Without the ability to spray chemical pesticides and fertilizers, small grains are a strong candidate for organic systems as they require less nitrogen fertilizer and naturally build fertility and manage pests and weeds in rotations (Marshall et al., 2013). Organic certification is both an operational factor in terms of whether the farmer chooses to pursue the certification, and a structural factor in that the certification requirements decided by the USDA can be expensive and time intensive.

Still, organic farmers struggle to make a profit from their small grains (Baker and Russell, 2017). A current small grain farmer from Illinois shared that, "The corn and beans are very profitable, the small grains portion of the operation is where we struggle to make money…The profitability on the corn and beans is what supports the organic operation, the small grains is what we do pretty much because we are required to have the three-crop rotation." Supporting the growing organic industry would allow more farmers to receive a premium for raising a product with resilient agricultural practices that include crop rotation.

Additional management. Extending a corn and soybean rotation to include a small grain means more planning and work (which we identify as an operational barrier), especially since small grains do not usually have set input packages nor the same technical or programmatic support (which we identify as a structural barrier). This is especially difficult as most farmers in the Upper Midwest no longer know how to grow small grains. A non-small grain farmer from Illinois encompassed the sentiment we heard across non- and discontinued small grain farmers when he explained, "I guess you get used to what you're doing sometimes. And maybe a better way to phrase it [is], until what we're doing isn't working might be when we would look to do something different…We want to be known as good farmers. So, it would have to still fit in that structure that we were getting stuff done timely, so. And it sounds weird, but you're throwing a third thing into the operation because, I know it's not just the planning of it. It's a different kind of spray…it's just a different part of our system in complexity that I don't know if it would work or not."

An agronomist echoed the farmers' thoughts when she explained, "I just feel like one way or the other, corn and soybean production has become the most convenient... It's still like a level of complexity or inconvenience that [farmers] just don't want to tackle anymore." In addition to market development and cost share incentives for planting small grains discussed above, greater educational outreach to non-small grain farmers via Cooperative Extension and other agricultural professionals is needed to emphasize the low-input, low-cost nature of small grains, their benefits in crop rotations, and to promote systems thinking in crop rotation and planning. In addition, farmers must know that it will pay to add small grains to a rotation to take the initial risk of adoption. More research is needed to quantify the economic benefits of diversified rotations that include small grains — the most common response when farmers were asked about research needs during interviews and focus groups.

7. Conclusion

Adding small grains in crop rotations is one of the most logical ways that corn and soybean farmers can diversify their systems, concurrently reaping a broad suite of agronomic and environmental benefits. Yet, through multiple methods and ways of knowing to better understand causality, we find there are a myriad of interconnected reasons why farmers in the Upper Midwest primarily plant only one to two crops and why diversifying to additional crops, in particular small grains, is challenging. Farmers identified markets and prices as the most important, yet abundant markets and high prices for corn and soybeans did not occur on their own. The proliferation of a crop requires a multifaceted approach including action and collaboration on the part of university researchers, Cooperative Extension, USDA, policy makers, seed companies, processors, food companies, farmers, farmer cooperatives, farmer organizations, and commodity groups.

In the case of policy, it is important to note that while we find that the small grain-specific elements of Farm Bill programs are less important to farmer-decision making compared to their markets and prices, that is not to say that policies are not important. Supports for marginal crops are less important compared to markets, but farmers in the region rely heavily on these programs for their primary cash crops: corn and soybeans. Without them, their return on investment would be substantially lower some years, making production riskier, and longer rotations with more crops more economically rational. Shifting subsidies to incentivize diversification and eliminating the corn ethanol mandate will go a long way to revalorize longer and more complex rotations. Additionally, decreasing support to fossil fuels will start to level the playing field for crops such as small grains that require less petroleum-based agrochemicals compared to corn.

Moreover, small grains, like most marginal crops, lack widespread advocacy organizations that promote their interests, a broader structural factor not captured in this research that focuses on the farmer perspective. Commodity associations similar to the Minnesota Wheat Research and Promotion Council and the National Barley Growers could be developed in other regions and for other small grains to promote research and development, and advocate for funding for market development and cost share in state and federal policy. Given the lack of acreage for many small grains, a broader, coordinated strategy that advocates across small grains, such as the Maryland Grain Producers Association, may be a promising way to collectively support the small grain industry.

We conclude that to enable strong agricultural markets and support farmers to produce small grains, it will be important to 1) invest in market development, on- and off-farm infrastructure, and improved varieties; 2) level the playing field with corn and soybeans in terms of subsidies and supply mandates; and 3) leverage the drivers of existing small grain acreage — certified organic production, the integration of crops and livestock, systems thinking, and cover crop use. While the order and importance of each is debated, just as there is a need for functional redundancy for ecosystem resilience (Walker, 1992), there is a need for "engineered redundance" (Naeem, 1998, p. 39) in the measures taken to change farmer behavior and the system in which it is embedded. Indeed, the gradual growth of corn and soybeans over the last century suggests that it is not one factor that is the key to unlocking wide-scale adoption, rather several factors that combine to move the needle. Each factor depends on the other to create an enabling environment in which the farmer is willing and able to adopt. Addressing each element shown to impact farmer decision making should be undertaken simultaneously in an iterative process to ensure that small grains have the same potential as corn and soybeans in the Upper Midwest.

Acknowledgements

This project was funded by Organic Valley Farmers Advocating for Organic, North Central SARE (see more below), the Cover Crops Research and Outreach Project, the Soil Health Collaborative, and Dr. Galt's W.K. *Kellogg* Foundation Endowed Chair Funding. We would like to thank our project advisory council for their thoughts and input in creating the survey, interview and focus group questions as well as their feedback on the results and recommendations: Dale Anderson (grain farmer), Roxann Brixen (Great American Insurance), Melissa Carlson (Minnesota Wheat Research & Promotion Council), Erik DeBliek (Grain Millers), Paul Dietman (Compeer Financial), Lydia English (Practical Farmers of Iowa), Anders Gurda (UW-Madison Organic Collaborative), Pat Murken (grain farmer), Halee and John Wepking (organic grain farmers and millers at Meadowlark Community Mill), and Jochum Wiersma (Extension Professor and Small Grains Specialist). We would also like to thank the farmers, academics, advocates, extension professionals, processors, crop insurance professionals, lenders, and buyers who took the time to share their thoughts and experience with us through survey responses, focus groups, interviews, and other communications.

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under agreement number 2020-38640-31522 through the North Central Region SARE program under project number GNC21-316. USDA is an equal opportunity employer and service provider. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

CRediT authorship contribution statement

LA led the research study; contributed to the grant writing, survey dissemination and design, interview and focus group protocol and facilitation, and writing and editing; conducted the data analysis; and managed the collaborative research process among the co-authors. MK, AH, and AM contributed to the grant writing, survey dissemination and design, interview and focus group protocol and facilitation, and provided edits and comments to the manuscript. RG and LP provided guidance on the research process throughout and contributed to the survey dissemination and design, focus group protocol, analysis, and editing. All authors contributed to the article and approved the submitted version.

References

Ajzen, I., 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alahmad, S., Rambla, C., Voss-Fels, K.P., Hickey, L.T., 2022. Accelerating Breeding Cycles, in: Reynolds, M.P., Braun, H.-J. (Eds.), Wheat Improvement: Food Security in a Changing Climate. Springer International Publishing, Cham, pp. 557–571. https://doi.org/10.1007/978-3-030-90673-3_30

Asprooth, L., Krome, M., Hartman, A., McFarland, A., Galt, R., Prokopy, L. (2023). Drivers and deterrents of small grain adoption in the Upper Midwest. East Troy, WI: Michael Fields Agricultural Institute.

Baker, B.P., Meints, B.M., Hayes, P.M., 2020. Organic barley producers' desired qualities for crop improvement. Organic Agriculture 10, 35–42. https://doi.org/10.1007/s13165-020-00299-y

Baker, B.P., Russell, J.A., 2017. Capturing a Value-Added Niche Market: Articulation of Local Organic Grain. American Journal of Agricultural Economics 99, 532–545. https://doi.org/10.1093/ajae/aaw100

Basche, A.D., Kaspar, T.C., Archontoulis, S.V., Jaynes, D.B., Sauer, T.J., Parkin, T.B., Miguez, F.E., 2016. Soil water improvements with the long-term use of a winter rye cover crop. Agricultural Water Management 172, 40–50. https://doi.org/10.1016/j.agwat.2016.04.006

Blesh, J., Galt, R., 2017. Transitions to Agroecological Nutrient Management Practices in the USA Corn Belt: Principles, Applications, and Making the Transition, in: Agroecological Practices for Sustainable Agriculture. pp. 85–126. https://doi.org/10.1142/9781786343062_0004

Bosco, F.J., Herman, T., 2010. Focus Groups as Collaborative Research Performances, in: The SAGE Handbook of Qualitative Geography. SAGE Publications, Inc., 1 Oliver's Yard, 55 City Road London EC1Y 1SP, pp. 193–207. https://doi.org/10.4135/9780857021090.n13

Bowles, T.M., Mooshammer, M., Socolar, Y., Calderón, F., Cavigelli, M.A., Culman, S.W., Deen, W., Drury, C.F., Garcia y Garcia, A., Gaudin, A.C.M., Harkcom, W.S., Lehman, R.M., Osborne, S.L., Robertson, G.P., Salerno, J., Schmer, M.R., Strock, J., Grandy, A.S., 2020. Long-Term Evidence Shows that Crop-Rotation Diversification Increases Agricultural Resilience to Adverse Growing Conditions in North America. One Earth 2, 284–293. https://doi.org/10.1016/j.oneear.2020.02.007

Bruce, D., Silva, E., Dawson, J., 2022. Cover crop-based reduced tillage management impacts organic squash yield, pest pressure, and management time. Frontiers in Sustainable Food Systems 6. https://doi.org/10.3389/fsufs.2022.991463

Buttel, F.H., 2006. The Handbook of Rural Studies, in: The Handbook of Rural Studies. SAGE Publications Ltd, London, pp. 213–229. https://doi.org/10.4135/9781848608016

Cameron, J., 2005. Focussing on the Focus Group, in: Iain Hay (Ed.), Qualitative Research Methods in Human Geography, 2nd Ed, Chapter 8. Oxford University Press, Melbourne, pp. 152–172.

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

Carlisle, L., 2014. Diversity, flexibility, and the resilience effect: lessons from a social-ecological case study of diversified farming in the northern Great Plains, USA. Ecology and Society 19. https://doi.org/10.5751/ES-06736-190345
Cochrane, W.W. (Willard W., 1993. The development of American agriculture: a historical analysis, 2nd ed. ed. University of Minnesota Press, Minneapolis.
Condon, N., Klemick, H., Wolverton, A., 2015. Impacts of ethanol policy on corn prices: A review and meta-analysis of recent evidence. Food Policy 51, 63–73. https://doi.org/10.1016/j.foodpol.2014.12.007
Corbin, J.M., Strauss, A., 1990. Grounded theory research: Procedures, canons, and evaluative criteria. Qual Sociol 13, 3–21. https://doi.org/10.1007/BF00988593
Davis, A.S., Hill, J.D., Chase, C.A., Johanns, A.M., Liebman, M., 2012. Increasing cropping system diversity balances productivity, profitability and environmental health. PLoS One 7, e47149. https://doi.org/10.1371/journal.pone.0047149
Deterding, N.M., Waters, M.C., 2021. Flexible Coding of In-depth Interviews: A Twenty-first-century Approach. Sociological Methods & Research 50, 708–739. https://doi.org/10.1177/0049124118799377
Dillman, D.A. author, 2014. Internet, phone, mail, and mixed-mode surveys: the tailored design method, Fourth edition. ed. Wiley.
Eller, D., 2017. Iowa has world's largest cereal plant, but state's farmers lack market for oats. The Des Moines Register.
FAO, 2022. FAOSTAT Database, Crops and livestock products [WWW Document]. URL https://www.fao.org/faostat/en/#data/QCL (accessed 4.25.23).
Fernandez-Cornejo, J., Just, R.E., 2007. Researchability of Modern Agricultural Input Markets and Growing Concentration. American Journal of Agricultural Economics 89, 1269–1275. https://doi.org/10.1111/j.1467-8276.2007.01095.x
Fishbein, M., Ajzen, I., 2010. Predicting and Changing Behavior: The Reasoned Action Approach, Predicting and Changing Behavior: The Reasoned Action Approach. https://doi.org/10.4324/9780203838020
Fleckenstein, M., Lythgoe, A., Lu, J., Thompson, N., Doering, O., Harden, S., Getson, J.M., Prokopy, L., 2020. Crop insurance: A barrier to conservation adoption? J. Environ. Manage. 276, 111223. https://doi.org/10.1016/j.jenvman.2020.111223
Forrest, N., Wiek, A., 2021. Growing a sustainable local grain economy in Arizona: Journal of Agriculture, Food Systems, and Community Development 10, 1-22-1–22. https://doi.org/10.5304/jafscd.2021.102.031
Friedman, H., McMichael, P., 1989. Agriculture and the state system: The rise and decline of national agricultures, 1870 to the present. Sociologia Ruralis 29, 93–117. https://doi.org/10.1111/j.1467-9523.1989.tb00360.x
Gaudin, A.C.M., Tolhurst, T.N., Ker, A.P., Janovicek, K., Tortora, C., Martin, R.C., Deen, W., 2015. Increasing Crop Diversity Mitigates Weather Variations and Improves Yield Stability. PLOS ONE 10, e0113261. https://doi.org/10.1371/journal.pone.0113261
Ghimire, B., Sapkota, S., Bahri, B.A., Martinez-Espinoza, A.D., Buck, J.W., Mergoum, M., 2020. Fusarium Head Blight and Rust Diseases in Soft Red Winter Wheat in the Southeast United States: State of the Art, Challenges and Future Perspective for Breeding. Frontiers in Plant Science 11. https://doi.org/10.3389/fpls.2020.01080
Graybosch, R.A., James Peterson, C., 2012. Specific adaptation and genetic progress for grain yield in Great Plains hard winter wheats from 1987 to 2010. Crop Science 52, 631–643. https://doi.org/10.2135/cropsci2011.08.0412

Halloran, A., 2015. The new bread basket: how the new crop of grain growers, plant breeders, millers, maltsters, bakers, brewers, and local food activists are redefining our daily loaf. Chelsea Green Publishing, White River Junction, Vermont.
Hart, J.F., 1986. Change in the Corn Belt. Geographical Review 76, 51–72. https://doi.org/10.2307/214784
Hendrickson, M., James, H., 2005. The Ethics of Constrained Choice: How the Industrialization of Agriculture Impacts Farming and Farmer Behavior. Journal of Agricultural and Environmental Ethics 18, 269–291. https://doi.org/10.1007/s10806-005-0631-5
Hitz, K., Clark, A.J., Van Sanford, D.A., 2017. Identifying nitrogen-use efficient soft red winter wheat lines in high and low nitrogen environments. Field Crops Research 200, 1–9. https://doi.org/10.1016/j.fcr.2016.10.001
Howard, P.H., 2016. AFHVS 2016 presidential address: Decoding diversity in the food system: wheat and bread in North America. Agric Hum Values 33, 953–960. https://doi.org/10.1007/s10460-016-9727-y
Hunt, N.D., Hill, J.D., Liebman, M., 2019. Cropping System Diversity Effects on Nutrient Discharge, Soil Erosion, and Agronomic Performance. Environ. Sci. Technol. 53, 1344–1352. https://doi.org/10.1021/acs.est.8b02193
Hunt, N.D., Hill, J.D., Liebman, M., 2017. Reducing Freshwater Toxicity while Maintaining Weed Control, Profits, And Productivity: Effects of Increased Crop Rotation Diversity and Reduced Herbicide Usage. Environ Sci Technol 51, 1707–1717. https://doi.org/10.1021/acs.est.6b04086
Ilbery, B., Bowler, I., 1998. From agricultural productivism to post-productivism.
Janovicek, K., Hooker, D., Weersink, A., Vyn, R., Deen, B., 2021. Corn and soybean yields and returns are greater in rotations with wheat. Agronomy Journal 113, 1691–1711. https://doi.org/10.1002/agj2.20605
Jin, Z., Gillespie, J., Barr, J., Wiersma, J.J., Sorrells, M.E., Zwinger, S., Gross, T., Cumming, J., Bergstrom, G.C., Brueggeman, R., Horsley, R.D., Schwarz, P.B., 2018. Malting of Fusarium Head Blight-Infected Rye (Secale cereale): Growth of Fusarium graminearum, Trichothecene Production, and the Impact on Malt Quality. Toxins 10, 369. https://doi.org/10.3390/toxins10090369
Johnson, C., Moriarty, K., Alleman, T., Santini, D., 2021. History of Ethanol Fuel Adoption in the United States: Policy, Economics, and Logistics (No. NREL/TP-5400-76260, 1832224, MainId:6072). https://doi.org/10.2172/1832224
Kim, C.S., Hallahan, C., Schaible, G., Schluter, G., 2001. Economic Analysis of the Changing Structure of the U.S. Flour Milling Industry. Agribusiness 17, 161–171.
Knight, J., 2003. A dying breed. Nature 421, 568–570. https://doi.org/10.1038/421568a
Lammers, P., 2017. Small Grains for Livestock: A Meta-Analysis. Sustainable Food Lab and Practical Farmers of Iowa.
Lighthall, D.R., Roberts, R.S., 1995. Towards an alternative logic of technological change: Insights from Corn Belt agriculture. Journal of rural studies 11, 319–334. https://doi.org/10.1016/0743-0167(95)00022-F
Lockeretz, W., 1988. Agricultural diversification by crop introduction: The US experience with the soybean. Food Policy 13, 154–166. https://doi.org/10.1016/0306-9192(88)90028-0
Lu, J., Ranjan, P., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Singh, A.S., Prokopy, L.S., 2022. A meta-analysis of agricultural conservation intentions, behaviors, and practices: Insights from 35 years of quantitative literature in the United States. Journal of Environmental Management 323, 116240. https://doi.org/10.1016/j.jenvman.2022.116240

Marshall, A., Cowan, S., Edwards, S., Griffiths, I., Howarth, C., Langdon, T., White, E., 2013. Crops that feed the world 9. Oats- a cereal crop for human and livestock feed with industrial applications. Food Sec. 5, 13–33. https://doi.org/10.1007/s12571-012-0232-x
Martí, J., 2016. Measuring in action research: Four ways of integrating quantitative methods in participatory dynamics. Action Research 14, 168–183. https://doi.org/10.1177/1476750315590883
McGhee, M.L., Stein, H.H., 2021. Inclusion of hybrid rye in diets for weanling pigs does not compromise daily gain, but may reduce diarrhea incidence despite pigs having preference for consuming corn over hybrid rye. Animal Feed Science and Technology 281, 115113. https://doi.org/10.1016/j.anifeedsci.2021.115113
McGranahan, D.A., Brown, P.W., Schulte, L.A., Tyndall, J.C., 2013. A historical primer on the US farm bill: Supply management and conservation policy. Journal of Soil and Water Conservation 68, 67A-73A. https://doi.org/10.2489/jswc.68.3.67A
Moore, V.M., Peters, T., Schlautman, B., Brummer, E.C., 2023. Toward plant breeding for multicrop systems. Proceedings of the National Academy of Sciences 120, e2205792119. https://doi.org/10.1073/pnas.2205792119
Mosier, N.S., Ileleji, K., 2006. How Fuel ethanol is Made from Corn. Purdue Extension.
Muckey, E., 2018. Small Grains in Minnesota: Assessing the Feasibility of Local Supply Chains (Report).
Naeem, S., 1998. Species Redundancy and Ecosystem Reliability. Conservation Biology 12, 39–45. https://doi.org/10.1111/j.1523-1739.1998.96379.x
Naylor, R.L., Falcon, W.P., Goodman, R.M., Jahn, M.M., Sengooba, T., Tefera, H., Nelson, R.J., 2004. Biotechnology in the developing world: a case for increased investments in orphan crops. Food Policy 29, 15–44.
Oatly, 2023. Resurrecting Oats in the US [WWW Document]. URL https://www.oatly.com/things-we-do/initiatives/resurrecting-oats-in-the-us (accessed 4.24.23).
Perfecto, I., 2009. Nature's matrix: linking agriculture, conservation and food sovereignty. Earthscan, London ; Sterling, VA.
Philpott, T., 2020. Perilous bounty: the looming collapse of American farming and how we can prevent it. Bloomsbury Publishing, New York, NY, USA.
Pollan, M., 2006. The omnivore's dilemma: a natural history of four meals. Penguin Press, New York.
Posner, E.S., Hoseney, R.C., 2015. A Century of Advances in Milling and Baking. Cereal Foods World 60, 148–153.
Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P., 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, 520–534. https://doi.org/10.2489/jswc.74.5.520
Rabalais, N.N., Turner, R.E., 2019. Gulf of Mexico Hypoxia: Past, Present, and Future. Limnology and Oceanography Bulletin 28, 117–124. https://doi.org/10.1002/lob.10351
Ramey, E.A., 2014. Farm Subsidies and Technical Change: State-Mediated Accumulation in U.S. Agriculture. Rethinking Marxism 26, 472–489. https://doi.org/10.1080/08935696.2014.947755
Rosenberg, K.V., Dokter, A.M., Blancher, P.J., Sauer, J.R., Smith, A.C., Smith, P.A., Stanton, J.C., Panjabi, A., Helft, L., Parr, M., Marra, P.P., 2019. Decline of the North American avifauna. Science 366, 120–124. https://doi.org/10.1126/science.aaw1313

Rosenzweig, S.T., Stromberger, M.E., Schipanski, M.E., 2018. Intensified dryland crop rotations support greater grain production with fewer inputs. Agriculture, Ecosystems & Environment 264, 63–72. https://doi.org/10.1016/j.agee.2018.05.017
Sadok, W., Wiersma, J.J., Steffenson, B.J., Snapp, S.S., Smith, K.P., 2022. Improving winter barley adaptation to freezing and heat stresses in the U.S. Midwest: bottlenecks and opportunities. Field Crops Research 286, 108635. https://doi.org/10.1016/j.fcr.2022.108635
Sandro, P., Kucek, L.K., Sorrells, M.E., Dawson, J.C., Gutierrez, L., 2022. Developing high-quality value-added cereals for organic systems in the US Upper Midwest: hard red winter wheat (Triticum aestivum L.) breeding. Theoretical and Applied Genetics 135, 4005–4027. https://doi.org/10.1007/s00122-022-04112-0
Sayer, 1992. Problems of explanation and the aims of social science, in: Method in Social Science: A Realistic Approach. Routledge, London ;, pp. 211–258. https://doi.org/10.4324/9780203163603
Shelton, A.C., Tracy, W.F., 2017. Cultivar Development in the U.S. Public Sector. Crop Science 57, 1823–1835. https://doi.org/10.2135/cropsci2016.11.0961
Shelton Janie F., Geraghty Estella M., Tancredi Daniel J., Delwiche Lora D., Schmidt Rebecca J., Ritz Beate, Hansen Robin L., Hertz-Picciotto Irva, 2014. Neurodevelopmental Disorders and Prenatal Residential Proximity to Agricultural Pesticides: The CHARGE Study. Environmental Health Perspectives 122, 1103–1109. https://doi.org/10.1289/ehp.1307044
Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L., 1999. A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. Human Ecology Review 6, 17.
Sulc, R., Tracy, B., 2007. Integrated Crop–Livestock Systems in the U.S. Corn Belt. Agronomy Journal - AGRON J 99. https://doi.org/10.2134/agronj2006.0086
Tautges, N.E., Burke, I.C., Borrelli, K., Fuerst, E.P., 2017. Competitive ability of rotational crops with weeds in dryland organic wheat production systems. Renewable Agriculture and Food Systems 32, 57–68. https://doi.org/10.1017/S1742170516000028
Thaler, E.A., Larsen, I.J., Yu, Q., 2021. The extent of soil loss across the US Corn Belt. Proc Natl Acad Sci U S A 118, e1922375118. https://doi.org/10.1073/pnas.1922375118
USDA NASS, 2022. 2022 Agriculture Survey. Washington, DC: USDA National Agricultural Statistics Service.
USDA-NASS, 2017. Census of Agriculture, Statistics by State [WWW Document]. URL https://www.nass.usda.gov/Statistics_by_State/ (accessed 5.18.22).
Vandermeer, J.H., 2018. Ecological complexity and agroecology, Earthscan book. Routledge.
Walker, B.H., 1992. Biodiversity and Ecological Redundancy. Conservation Biology 6, 18–23.
Ward, N., 1993. The Agricultural Treadmill and the Rural Environment in the Post-Productivist Era. Sociologia Ruralis 33, 348–364. https://doi.org/10.1111/j.1467-9523.1993.tb00969.x
Weisberger, D.A., McDaniel, M.D., Arbuckle, J.G., Liebman, M., 2021. Farmer perspectives on benefits of and barriers to extended crop rotations in Iowa, USA. Agricultural & Environmental Letters 6, e20049. https://doi.org/10.1002/ael2.20049

Dissertation Conclusion

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In this dissertation, I examine a portion of the drivers of and barriers to a transition to regenerative agriculture in the Corn Belt with a focus on the grassroots efforts of farmer organizations and top-down policy mechanisms through the Farm Bill. Together with my project collaborators, I find that multiple drivers and barriers exist crossing operational, structural, social, and biophysical realms. The first chapter shows that farmer networks matter to farmer decision making and can be especially impactful when peer exchange is paired with knowledge from experts in a formalized network. The second chapter unpacks the specific roles the PFI network plays in supporting a transition to conservation practices, and the most important aspects of the network according to its member farmers. We inductively identify a "recipe of success" for farmer networks and other organizations working with farmers to create the most change on the landscape.

The third chapter shows that a range of factors are important to farmer decision making regarding cropping decisions in the Upper Midwest. Markets and prices, regional growing conditions, and added management are primary barriers to adding small grains to corn and soybean operations. Access to equipment, improved small grain varieties, and the timing of planting and harvesting can be both drivers and barriers, depending on the farmer. Cost share programs, livestock, organic certification, the system benefits of small grains, and the synergies between small grains and cover crops are found to be drivers of small grain production. The availability of Farm Bill programs specifically for small grains including crop insurance, revenue supports, and loans, were comparatively less important.

Across Chapters 1 and 3, I find commonalities in terms of the positive association with participation in EQIP and the adoption of conservation practices. Shown by several academic reviews of the adoption of agricultural conservation studies (Carlisle, 2016; Knowler and Bradshaw, 2007; Prokopy et al., 2019), I provide further evidence of the important role of incentives paired with one-on-one technical support to motivate farmers to try a new practice. Neither study finds that individual- and farm-level characteristics of farmer age, farm size, and land ownership are associated with the adoption of small grains or conservation practices. The inconsistency of individual demographic and farm characteristics as a predictor of adoption is supported by a review of quantitative adoption literature in agriculture by Prokopy et al. (2019).

Taken together, these studies suggest that our path forward in agriculture is not a simple one. The cause of the ecological, social, and economic predicament of agriculture in the Corn Belt is complex and cannot be narrowed to one set of reasons, as I hope this research has shown in some part. As political ecologists, we are often too quick to turn to governmental action as both the cause of and solution to issues in agriculture, to the detriment of other important factors. This focus shields an unproductive penchant against our political system embedded in the field. Sociologists and other scientists in the social sciences of agriculture studying adoption, on the other hand, tend to leave out these institutional factors in favor of social ones such as networks, farmer attitudes, and individual and operational characteristics that, while often more fruitfully engaging with the agency of the farmer than political ecologists, cannot predict farmer behavior without a broader scope. And, at the continued risk of some oversimplification, those in the biophysical sciences turn their attention towards the role of agronomic and plant sciences to improve production at the field-level and therefore encourage adoption.

I focus on two poles of change—the power of institutions to affect the behaviors of others, and the agency of individual actors to make choices on their own free will. However, the results show that it is not just farmer grassroots efforts nor just top-down policy mechanisms that drive farmer decision making. It also biophysical factors that can be bettered by the work of our colleagues in the biophysical sciences. And it is markets, an element that crosses individual, economic, and structural fields, that must be addressed at multiple scales (from direct-to-consumer markets to ingredients in major food brands) and by multiple parties (economists, supply chain experts, food companies, and policy makers). It is a range of elements that evidence the complex and multifactoral environment that shapes farmer decision making. All of these factors must be addressed through an iterative process using a multipronged approach to creating change, and one that considers the true complexity of the system.

Just as there are a multitude of factors that impact farmer decision making, there are a multitude of actions that must be taken to support farmers to transition. That is not to say that some actions will not have more impact than others. The second part of this research finds that the small grain-specific elements of Farm Bill programs are less important to farmer-decision making compared to their markets and prices. Still, while supports for marginal crops are less important compared to markets, farmers in the region rely heavily on these programs for their primary cash crops: corn and soybeans. Without them, their return on investment would be substantially lower some years, making production riskier, and longer rotations with more crops more economically rational. Crop insurance, combined with the corn ethanol supply mandate in the Renewable Fuel Standard (RFS), are two key policy mechanisms that have the potential to dramatically change agricultural production practices. However, the reality remains that the reversal of the RFS and major changes to crop insurance lack political support and are highly unlikely in the near-term. As leaders in agriculture increase awareness and support for these changes, especially amongst farmers and the groups with lobbying power that represent them, we must be simultaneously working to address other important elements shown to impact farmer decision making.

To transition to regenerative agriculture in the Corn Belt, we will need increased collaboration across researchers, leadership in private industry, NGOs, and, and policy makers to create improved inputs and practices for conservation agriculture, risk management tools that incentivize diversification, processing infrastructure to support a range of farm products, peer support and education on alternative practices through farmer networks, and sourcing commitments from food companies to purchase local products grown using conservation practices. At a broader scale, we must also reduce the influence in our political system of agribusiness companies that promote chemical agriculture within in a system of unfettered capitalism (Kloppenburg et al., 1996; Lewontin, 1998). Regulating consolidation in agribusiness both in terms of input suppliers and processors can help farmers receive a larger share of the profit and afford more economical ease at which to trial different practices (Galt, 2013; Hendrickson and James, 2005).

Moving forward, I plan to continue this work in the following ways. From the small grains study, I am in the process of developing a crop insurance for small grains fact sheet for the University of Wisconsin Organic Grain Research and Information Network (OGRAIN), along with a second academic paper focusing on the farm policy factors including crop insurance, cost share, and revenue supports titled: "Our daily bread in the Heartland: What does Farm Policy have to do with it?" This paper will examine the history of diversification and farm safety net and conservation programs in the US, unpack the survey, interview, and focus group data in more detail regarding Farm Bill programs, and provide concrete policy recommendations on how to improve these programs to support diversification from corn and soybeans to third crops like small grains. In addition, I hope to conduct a spatial analysis using the survey data collected through this project to understand whether proximity to urban centers, processors, and other buyers is associated with a farmer's decision to grow small grains.

My future research will continue to build upon my dissertation through my work in two institutions: Purdue University and the University of Wisconsin, Madison. I began working as a research consultant, and will soon become a half-time post-doc, at Purdue University with Dr. Linda Prokopy through the Diverse Corn Belt project, a multi-institution USDA NIFA seeking to understand how to support diversification from corn and soybeans in the states of Iowa, Illinois, and Indiana. Through this project, I have expanded my focus from small grains to a range of agricultural products that make up a diverse landscape. I will analyze farmer survey and interview data to understand constraints and opportunities to diversification, and work with farmers and project colleagues on re-envisioning a diverse agricultural landscape. I will spend the other half of my time working as a research scientist at the Center for Integrated Agricultural Systems at the University of Wisconsin–Madison led by Dr. Erin Silva. In this role, I will work to understand farmers' willingness to adopt soil health improving practices, or in other words, under what environmental, economic, educational, and social outcomes would a farmer be most willing to change their practices. I see this work as an all-encompassing "what's it going to take" approach to narrowing in on the exact scenarios that could move the needle of change in agriculture.

More research is needed to build upon this work to understand how to create the right enabling environment in which farmers can transition to regenerative agriculture. Regarding small grains, more work is needed to explore the ways in which markets for small grains can be developed and promoted in the Upper Midwest. In terms of farmer networks, studies of other formal farmer networks would be useful to understand if the facets that make the PFI network effective are shared across other networks. At the policy end, studies are needed to assess the impacts on cropping decisions of the removal of direct payments to farmers for commodity production, assess farmer perceptions of the renewable fuel standard and participatory visioning of a pathway away from ethanol markets, and compare the successful state-administered cover crop incentive program in Maryland to programs in other states.

To create more impact and reach farmers, it will be incredibly important to conduct applied and farmer-engaged research in addition to policy-relevant research. This entails expanding our idea of what successful research looks like to include nonacademic publications, time spent collaborating with partner organizations including farm organizations, and attention to how research can be co-created with farmers. Forging partnerships with the organizations that represent the majority of the farming population in the Corn Belt including the Farm Bureau, national and state Farmers Unions, and corn, soybean, and livestock commodity groups to find solutions and ensure their buy-in is essential. It will be near impossible to change the core functioning of commodity-specific farm bill programs and supply mandates like the RFS — those that will have the greatest impact on agricultural practices — without these organizations on board. Building trust and finding common ground with these groups through efforts to combat corporate oligopsony and oligopoly power in agriculture and help farmers capture more of the profit in the supply chain is a promising start.

This research does not address all of the ways to overcome the problems of the current agricultural landscape. But to the extent that our current systems render farmers unable to change, this research addresses pathways to encourage farmers to make decisions that are in the best interest of their communities and their environments in the long-term. It is my hope that the findings can make even some impact on the ability of farmers and decision makers in agriculture to create an agriculture filled with vibrant, diverse operations producing foods that nourish ourselves, our communities, our livestock, and the land.

References

Galt, R.E., 2013. Placing Food Systems in First World Political Ecology: A Review and Research Agenda. Geography Compass 7, 637–658. https://doi.org/10.1111/gec3.12070

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

Hendrickson, M., James, H., 2005. The Ethics of Constrained Choice: How the Industrialization of Agriculture Impacts Farming and Farmer Behavior. Journal of Agricultural and Environmental Ethics 18, 269–291. https://doi.org/10.1007/s10806-005-0631-5

Kloppenburg, J., Hendrickson, J., Stevenson, G.W., 1996. Coming in to the foodshed. Agric Hum Values 13, 33–42. https://doi.org/10.1007/BF01538225

Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy 32, 25–48. https://doi.org/10.1016/j.foodpol.2006.01.003

Lewontin, R.C., 1998. The Maturing of Capitalist Agriculture: Farmer as Proletarian. Monthly Review 72–84. https://doi.org/10.14452/MR-050-03-1998-07_6

Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B.M., Ranjan, P., 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, 520–534. https://doi.org/10.2489/jswc.74.5.520