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Soil health through farmers' eyes: Toward a better understanding of how farmers view, value, and manage for healthier soils

R. Irvine, M. Houser, S.T. Marquart-Pyatt, G. Bogar, L.G. Bolin, E. Grennan Browning, S.E. Evans, M.M. Howard, J.A. Lau, and J.T. Lennon

Abstract: Improved soil health (SH) is critical in achieving agricultural resilience and mitigating climate risks. Whether SH management practices are widely used depends greatly on US farmers' voluntary decision-making. Toward understanding this point, much research has addressed factors that contribute to the adoption (or lack thereof) of SH-promoting practices, but less is known in terms of farmers' perceptions of SH itself and the corresponding management practices they see as related to achieving SH. To offer introductory insight on this knowledge gap and support better buy-in from farmers toward positive SH outcomes, our research draws upon qualitative interviews with 91 farmers across three key agricultural states in the Midwest (Illinois, Indiana, and Michigan). We develop a more detailed understanding of farmers' views on SH, and why and how they manage for it. Nearly all interviewed farmers were familiar with the concept of SH and most viewed it favorably. A minority of farmers lacked familiarity with the term "SH" yet still managed for it. Skeptics of SH largely cited uncertainties related to over-zealous messaging by proponents of SH or lack of evidence for the return on investment of SH practices. Overall, farmers' perceptions of SH largely aligned with the scientific community's understanding of soils being a dynamic system, though farmers most dominantly defined SH by its biological component. Farmers perceived a host of benefits of SH, most often noting benefits to production, followed by improvements in physical aspects of the soil such as erosion control and increased organic matter. Notably, production and sustainability benefits were often cited together, suggesting that SH management is increasingly seen as a "win-win" by farmers. Additionally, we found that many farmers view themselves as active participants in SH outcomes and believe their management choices are indicators of positive SH outcomes, regardless of the practices they employ, including some strategies (such as tillage or tile drainage) that do not align with scientifically documented approaches to improving SH. Our findings show that farmers report engaging in an array of SH management practices that target both biotic and abiotic components of soils, and often use multiple practices in tandem to promote SH on their farms. Achieving better SH in agricultural production in the future will require engaging farmers in SH management by tailoring outreach and communication strategies to align with the perspectives and language farmers themselves use to conceptualize SH.

Key words: conservation agriculture—farmer attitudes—farmer beliefs—natural resource conservation—stakeholder engagement—soil health management

Agricultural production in the United States must become more resilient to the growing occurrence of extreme weather (Walthall et al. 2013), while also mitigating contributions to environmental problems such as climate change, biodiversity loss, and water quality degradation (Basso et al. 2021; Campbell et al. 2017; Matson et al. 1997). The promotion of soil health (SH) is increasingly seen as a key means to achieve these ends (Lehman et al. 2015; Montanarella 2015). While the definition of SH continues to evolve over time (Karlen et al. 2017; Wander et al. 2019), it can be broadly understood as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans" (USDA NRCS 2012). Healthy soils are generally seen as the product of a dynamic, complex system comprised of physical, chemical, and biological components and the interactions that occur between them (Moebius-Clune et al. 2016).

Researchers and policy makers increasingly recognize the important role that SH plays within climate mitigation and adaptation strategies. SH has become an integral part of innovating farm management practices to promote resilience (Wirth-Murray and Basche 2020). On this front, scientific research on SH is focusing on effective and efficient ways to measure and improve SH and quantify its associated benefits (Morgan and Cappellazzi 2021; Stewart et al. 2018). Relatedly, policy makers, industry, and con-

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Rachel M. Irvine has a Master of Science in Environmental Science, Policy, and Management and is an environmental researcher at the Environmental Resilience Institute and at The O'Neill School of Public and Environmental Affairs at Indiana University, Bloomington, Indiana. **Matthew Houser** is an applied social scientist and regenerative agricultural fellow dually appointed at The Nature Conservancy Maryland/DC Chapter and the University of Maryland Center for Environmental Sciences, Horn Point Laboratory, Easton, Maryland. **Sandra T. Marquart-Pyatt** is a professor in the Department of Geography, Environment, and Spatial Sciences and the Department of Political Science at Michigan State University in East Lansing, Michigan. **Glade Bogar** is a postdoctoral researcher at Kellogg Biological Station, Michigan State University, East Lansing, Michigan. **Lana G. Bolin** is a doctoral candidate in the Department of Biology at Indiana University, Bloomington, Indiana. **Elizabeth Grennan Browning** is an assistant professor in the Department of History at University of Oklahoma, Norman, Oklahoma. **Sarah E. Evans** is an associate professor at Michigan State University's W.K. Kellogg Biological Station in southwest Michigan, and a member of the Department of Integrative Biology and the Ecology, Evolution and Behavior Program, Hickory Corners, Michigan. **Mia M. Howard** is a postdoctoral researcher in the Department of Biology at Indiana University, Bloomington, Indiana. **Jennifer A. Lau** is an associate professor in the Department of Biology at Indiana University, Bloomington, Indiana. **Jay T. Lennon** is a professor in the Department of Biology at Indiana University, Bloomington, Indiana.

servation actors have undertaken strategic engagement and outreach efforts to increase farmers' awareness of SH to ultimately encourage farmers to pursue SH management (Arbuckle et al. 2016; Karlen et al. 2017; Soil Health Institute 2019). The push for healthier soils is well underway.

However, recent research suggests an emergent barrier to the success of these efforts: US farmers' perceptions of SH are not well understood and are often misperceived by SH outreach and engagement organizations (Wade et al. 2021; Wirth-Murray and Basche 2020). For instance, comparison of farmers' views of SH with those of USDA Natural Resources Conservation Service (NRCS) staff and academics' interpretations of farmers' views revealed that nonfarming groups tend to underestimate the importance farmers place on SH (Wade et al. 2021; Wirth-Murray and Basche 2020).

Limited knowledge and misperceptions of farmers' views on SH speaks directly to the need for more work on this topic, as ineffective communication between conservation organizations and farmers hampers efforts to advance the adoption of SH practices. To date, most social science literature related to SH has taken a practice-centric approach, examining farmers' views or use of specific practices to build SH (e.g., no-tillage and cover crops) (Prokopy et al. 2019; Yoder et al. 2021; Roesch-McNally et al. 2018c). While this work has generated key insights into the drivers of and barriers to SH-related practice adoption, our knowledge of farmers' perceptions of and motivations related to SH as a specific concept (rather than the practices used to promote it) is limited. A few recent studies addressed these topics, primarily relying on large-scale surveys, and found that farmers are generally supportive of SH, at least in the midwestern United States (Arbuckle 2017; Wade et al. 2021).

Looking to the future, effectively engaging farmers in SH management depends on place-specific tailoring of outreach and communication strategies that matches the perspectives and language of farmers themselves (Reimer et al. 2014; Bagnall et al. 2020). Social scientists focused on SH are well-positioned to address emergent barriers to behavioral change; however, more research is needed on the topic, particularly qualitative approaches that can complement the existing literature. At present, few researchers have used qualitative approaches to document US farmers' views on SH (c.f. Bagnall et al. 2020). In this study, we build on this body of work and add place-specific depth to the understanding of farmers' views on SH via qualitative interviews. Qualitative interviews offer rich insights that can be an effective tool to inform outreach, communication strategy development, and future research (Doll et al. 2017; see Prokopy [2011] for a full discussion on the importance and role of qualitative methods in agricultural research). Our central goal and broader contribution are to give voice to midwestern farmers' multifaceted understanding of SH and SH management. Toward this end, we address the following three primary research questions related to farmers' perceptions and management of SH:

1. How familiar are farmers with SH, how favorably do they view it, and what factors do they perceive as contributing to "healthy" soil?
2. What are the benefits or goals farmers hope to derive from healthy soil?
3. What management practices do farmers use to promote SH?

We address these questions by drawing on 91 in-depth interviews with midwestern row crop farmers. Our qualitative analysis provides insights into farmers' perceptions of SH and the corresponding management practices they employ to achieve their aims. Our work also identifies points of alignment and potential misunderstandings that exist between farmers' views and the current scientific and academic understanding of SH as a dynamic system of interwoven physical, chemical, and biological components. This study's results promote a grounded take on why farmers "do what they do," and contributes a unique, in-depth perspective to the emerging social science literature on SH. We expect our findings can contribute to improved outreach, engagement, and policy efforts so that they better align with what farmers want and need to promote SH, thereby contributing to more desirable SH outcomes and increased agricultural resiliency in the midwestern United States.

Materials and Methods

Study Context. Our work focuses on row crop farmers in the midwestern United States, a key agricultural region that produces a substantial portion of the country's commodity crops (USGCRP 2018). However, agricultural production in the region both faces and contributes to considerable environmental risks. Midwestern agricultural resilience is threatened by emerging climate change impacts, including the growing frequency of agricultural droughts, heavy rain events, and flooding (Angel et al. 2018). Agricultural practices in the region also contribute to the degradation of its soils (Thaler et al. 2021) and water quality, especially in the midwestern Corn Belt and Mississippi River watershed, respectively (David et al. 2010; Jacobson et al. 2011). Consequently, midwestern farmers are important stakeholders in the mitigation of climate risks and the development of greater regional environmental resiliency. Because farmers work with soil more directly and on a larger scale than any other sector of the population, their perspectives and subsequent SH practices affect the trajectory for SH outcomes across a large spatial and temporal scale. Here, we study farmers' views on SH across three key agricultural states in the Midwest: Illinois, Indiana, and Michigan. These states are generally representative of the Upper Midwest row crop system, facing similar climatic and water quality challenges, while also being major agricultural production engines in terms of commodity corn (*Zea mays* L.) and beans (*Glycine max* L.). Specifically, these three states harvested approximately 22% of the nation's corn in 2020 (Illinois: 13.3%, 11 M ac [~4.45 M ha]; Indiana: 6.3%, 5.25 M ac [~2.12 ha]; and Michigan: 2.4%, 1.99 M ac [~805,000 ha]) (USDA NASS 2021). For these reasons, improved SH management is particularly key to achieve within our three study states and across the midwestern agricultural region. While we do not anticipate that our results will apply precisely to all midwestern states and producers, we do argue that farmers' views in these states are suggestive of those across the broader region and serve as a foundation for future, more generalizable research.

Data Collection and Analysis. To understand how farmers in this study area view and manage for SH, we interviewed 91 row crop farmers across three states (Illinois [IL] = 30; Indiana [IN] = 32; Michigan [MI] = 29). We drew our sample contacts from Marquart-Pyatt (2022), an ongoing, longitudinal survey of midwestern row crop farmers. The self-administered mail survey has been conducted annually since 2017 with a stratified, representative sample of row crop farmers in four states in the eastern Corn

Belt (Illinois, Indiana, Michigan, and Ohio). Approximately 2,500 row crop farmers complete the survey each year. Our sample was drawn from the fourth wave of this multiyear study, fielded in 2020. This sample is representative of US corn–soy growers in the eastern Corn Belt.

We selected a subsample of potential interviewees for each state to ensure representation of irrigating and dryland farmers, the latter of which were further selected with varying attributes such as farming experience, farming practices, and geography. We designed our interview pool to maximize the variability within and across groups and states, with roughly equal proportions of farmers in each. Contact information was drawn from a combination of sources, including information supplied by the survey respondents and supplemented by a mailing list purchased from a vendor. All farmers in our interview pool had agreed to be contacted for future research. We conducted our interviews over the course of five-months, from January to May of 2021. From the initial pool of contacts, we completed 91 interviews; a subset of contacts declined participation (n = 39), and a portion of contacts were unavailable or not reachable (n = 169).

Three research technicians conducted the one-on-one interviews with the farmer participants; interviews were conducted over the phone rather than in person, due to COVID-19 safety precautions, and lasted between 21 and 104 minutes, with an average length of 53 minutes. A semistructured interview guide was used during each interview. It included questions about farm characteristics, experiences with extreme weather events, SH management, and irrigation use, among other topics. Farmers were mailed a US$50 gift certificate for their participation. All interviews were audio-recorded, transcribed verbatim, and thematically coded. Codes were based upon interview questions (Saldaña 2016) and/or related emergent themes (see supplemental table S1) pertaining to farmers' SH management and perceptions (e.g., use of manure or biologicals; environmental conservation ethic; previous use of livestock or more diverse crop rotation). Specific interview questions were asked about each of the research questions addressed herein, including farmers' familiarity with, perceptions of, and practices used to achieve SH, among other specific questions related to SH. The lead author led coding/theme development using NVivo software (QSR International, Burlington, Massachusetts). When comments did not clearly fit into a specific code, the first and second author collaboratively determined the most appropriate thematic interpretation.

Results and Discussion

Our study sought to answer three research questions related to midwestern (Illinois, Indiana, and Michigan) farmers' perceptions and management of SH. Specifically, our research addressed farmers' perceptions of (1) what makes soil healthy, (2) what benefits they seek from healthy soil, and (3) what management practices they employ to promote SH. Our analysis aimed to identify regional-level trends in farmers' views on these topics. Our results suggested that farmers are widely familiar with the concept of SH, but some differences existed in terms of their attitudes toward SH and their interpretations of management actions to promote SH. In terms of the perceived benefits of healthy soil, farmers emphasized production-related benefits, improvements to soil biology, and improvements in abiotic components of SH (e.g., soil structure and water holding capacity). Finally, farmers described using a wide variety of practices to intentionally build SH, predominately emphasizing tillage-based practices and efforts to keep a living root in the soil (e.g., by planting cover crops). However, some farmers did employ strategies that do not align with scientifically documented approaches to improve SH and which will likely accelerate agriculture's negative environmental consequences. We discuss these findings in more detail below.

Differing Perspectives on "What Makes Soil Healthy." Regarding familiarity with and attitudes toward "soil health," of the 91 farmers who were interviewed, most were familiar with SH and expressed positive attitudes toward it. Nearly all (n = 87; 96%) self-reported that they were familiar with the term "soil health." Of the four farmers who lacked familiarity, three were unfamiliar with the specific term "soil health," while one misinterpreted it as another term for organic farming ("Sort of more organic farming type thing?" [ILD004]). However, initial lack of familiarity with the term itself did not necessarily mean a lack of understanding or support toward SH. Two farmers who were initially unfamiliar with "SH" expressed favorable attitudes toward it after "SH" was described by interviewers as "Efforts to nourish the soil for long-term fertility, especially in ways that minimize the use of chemical inputs." This expanded explanation of SH varies somewhat from the definition of soil health as defined by NRCS (2012); this language choice was intentional to ensure the language used to describe SH to farmers during interviews was accessible and ultimately resonated with this audience. After interviewers then asked the follow-up question, "Is that something that you try to achieve?", these farmers emphatically agreed that they were SH proponents and indicated that they were trying to promote SH on their farms:

- "Well yeah, man, I like to think so." (ILD006)
- "Yes. And double, yes." (MID001)

Though only two farmers expressed a positive outlook on SH despite not having prior familiarity with the term itself, this does suggest an important point: a minority of farmers may be in favor of and/or practicing SH management but are not familiar with the concept by name.

Most interviewees viewed SH favorably (n = 83; 91%), although they did so to varying degrees. The strongest SH advocates tended to profess their adherence to SH proudly. As one farmer put it, "I believe in it very strongly. I've even attended the Soil Health Academy. I'm a very big proponent of it" (ILI001). Similarly, another noted, "I'm sold on soil health, I can tell you that." However, not all interviewees were as strongly "sold" on SH. As noted before, initial familiarity with SH did not always correspond with attitude toward SH. Some farmers (n = 6; 7%) were familiar with SH but expressed skepticism or an outright negative outlook on SH for a variety of reasons. Notably, some farmers were skeptical toward SH because of how adamantly its proponents tended to promote its benefits at professional meetings:

> I've heard a lot of different presentations [on soil health]. I'll usually go to a couple of them a year. I agree with a lot of what they're saying. I don't agree with it all. […] I think sometimes, in trying to sell a program, people try to make it sound like it's going to work on every acre and, and a lot of these programs will not. And, I think they've oversold some of it and people, they use it and they run into some issues, and because of that, they'll go completely away from it. […] I like the idea of adapt-

ing to what my situation is on any given field. And I think that's the way things should be presented. (INI005)

Similarly, the prevalence of SH in various media outlets generated skepticism toward SH amongst some farmers who seemed to view SH as a trending management practice, but one which lacked evidence. Farmers who ascribed to this perspective seemed to believe that SH did not merit their attention or investment of resources:

- "[Soil health] is all over the magazines and social media. I've paid attention to it, but I don't know how much of it I actually believe." (IND006)
- "I've heard some about it and right now we haven't jumped on that bandwagon yet. We're just kind of observing it." (ILD007)

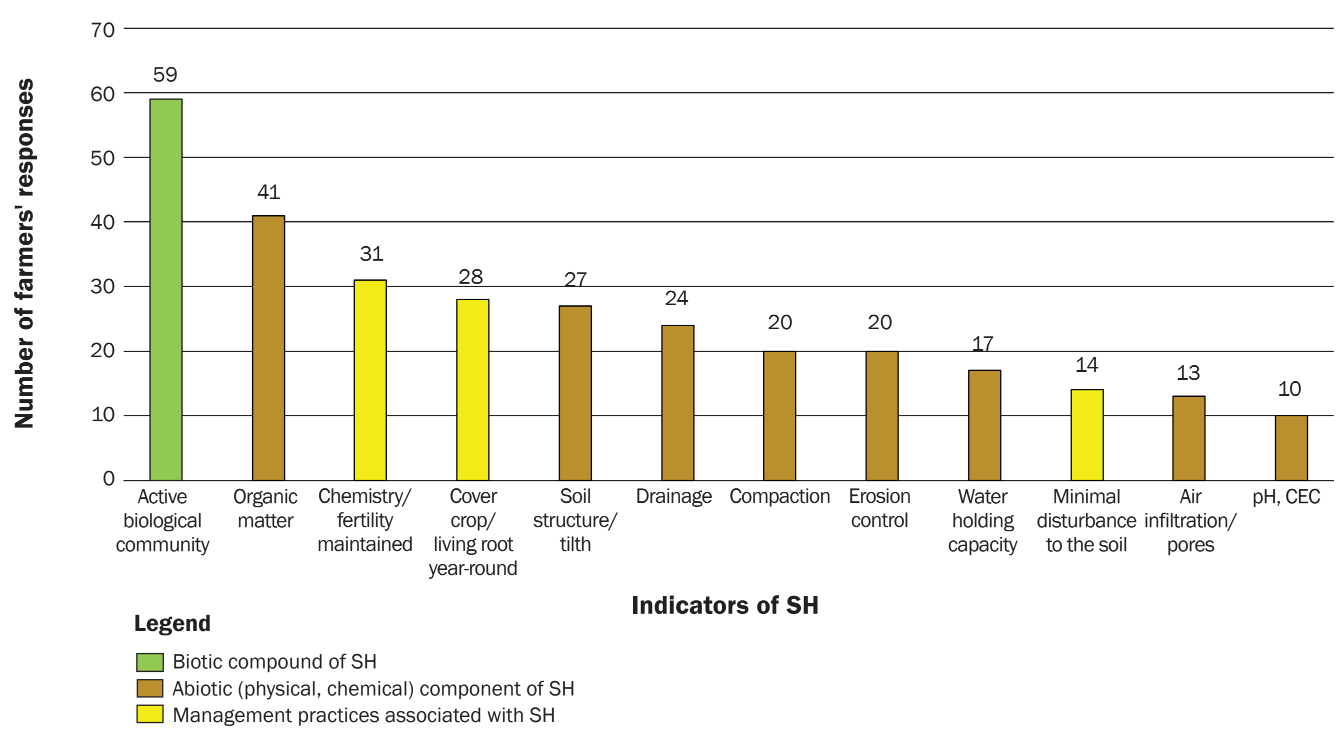
Additionally, other farmers expressed negative views toward SH based on their skepticism that SH can be improved or a perceived discrepancy between the purported benefits of SH and the return on investment from SH management practices: "I'm not convinced that [soil health is] something that can be changed that quickly (in terms of a farmers' management). And the economics of it?... I'm not sure that makes sense" (ILD014). Furthermore, some farmers believed that focusing on SH had harmed fellow "early adopter" farmers (Rogers 2003); such farmers were consequently hesitant to endorse SH: "A couple people tried to preach [SH] to me back in the '90s with biologicals and soil amendments. A couple of my friends went broke doing that... I never saw a benefit to it" (IND020). While most farmers view SH favorably, the skepticism and negative attitudes toward SH that are expressed by some farmers are important for the future development of clear and strategic SH communication to better engage some farmers.

Diverse interpretations of "soil health" among farmers were also recorded in addition to variability in farmers' familiarity with and attitudes toward SH. Soils are complex systems comprised of physical, chemical, and biological components. There is ongoing debate in the scientific community around the relative importance of each component and how to quantify "SH" (Yang et al. 2020). Further compounding the ambiguity around the term "soil health" is the evolution and proliferation of related terminology that has been used to describe soils in the past and present (Baveye 2020). The lack of consensus surrounding language to describe soils in the scientific community provides further support for the importance of understanding farmers' conceptualization of and language used to describe soils and their associated farm management practices. Farmers' familiarity with the three core aspects of SH (physical, chemical, and biological properties), and specifically what indicators they feel represent or manifest "healthy soils," matter for the actual practices they take to manage their soil and in shaping engagement and outreach to promote the adoption of better SH practices (Bagnall et al. 2020).

Interviewed farmers were often aware of both abiotic (physical and chemical) and biotic components of SH (figure 1, visual-

Figure 1

Farmer-identified indicators of soil health (SH)/what makes soil healthy; items were identified by at least 10 midwestern farmers and are related to either the abiotic or biotic components of SH, or management practices that farmers associate with SH.



ized in brown and green, respectively), and of interactions between them. Farmers often discussed SH in a granular fashion, self-identifying multiple indicators related to biotic and abiotic components of SH. Across the 90 farmers who discussed their interpretation of SH, or what makes soil healthy, thematic analysis yielded 18 items, 12 of which were identified by at least 10 farmers (figure 1; table S2 in supplemental material). Most farmers (n = 84; 93%) conceptualized SH as being comprised of multiple indicators ($\bar{x}$ = 4); nevertheless, a handful of farmers (n = 6; 7%) described SH in terms of just 1 indicator, while one farmer listed as many as 11 indicators of SH. Of the 91 farmers interviewed, one individual (IND019) was excluded from the analysis because they indicated they were not familiar with SH and it was not a focus of their farm management.

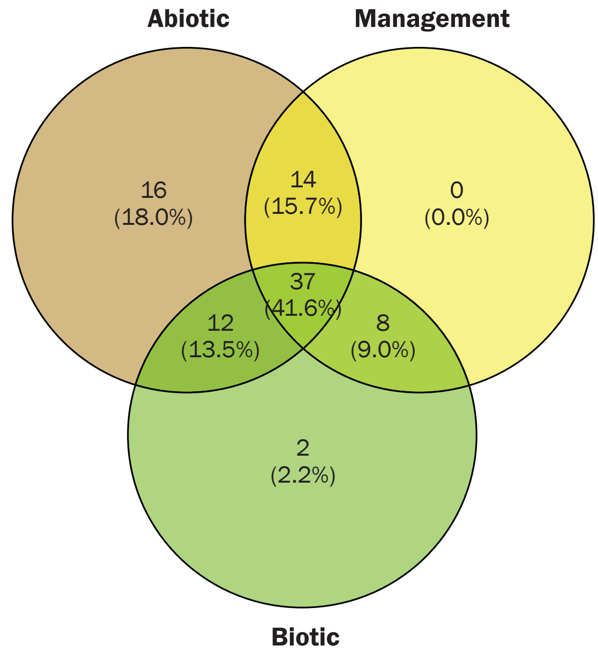
Relatively few farmers identified SH solely from an abiotic or biotic perspective (n = 16, 18%; n = 2; 2%, respectively) (figure 2). The majority of farmers (n = 49; 55%) conceived of SH as a combination of indicators associated with both the biotic and abiotic dimensions of soil (figure 2). As one farmer described SH,

> It's kind of a balance. In my opinion, it's a balance between microbe activity and the right amount of nutrients to grow a crop without over fertilizing or under fertilizing, and building the structure of the soil to where you get good root movement, good water absorption and try to keep it that way without screwing it up with compaction or working something wet. That's my knowledge of it, that's a generalization of what I feel like is soil health. (IND004)

Of the farmers who conceptualized SH as a mix of biotic and abiotic indicators, some emphasized one or the other. Overall, farmers most often described SH using indicators associated with the biotic component of SH. Over two-thirds of respondents (n = 59; 66%) noted the importance of biological activity to SH (figure 1), either in reference to soil as a living organism, better nutrient cycling due to biological activity, or in explicit reference to earthworms, bacteria, fungi, and/or microbes. Our finding that biological activity was the most commonly cited indicator of SH by farmers parallels the current focus on the biological (especially microbial) components of SH by the scientific community (Coyne et al. 2022).

Figure 2

Components of soil health (SH), by category, as conceptualized by midwestern farmers. Categories were developed by thematically grouping farmer-generated indicators of SH into abiotic (A) and biotic (B) components of SH, and/or management practices (M) farmers associated with SH.

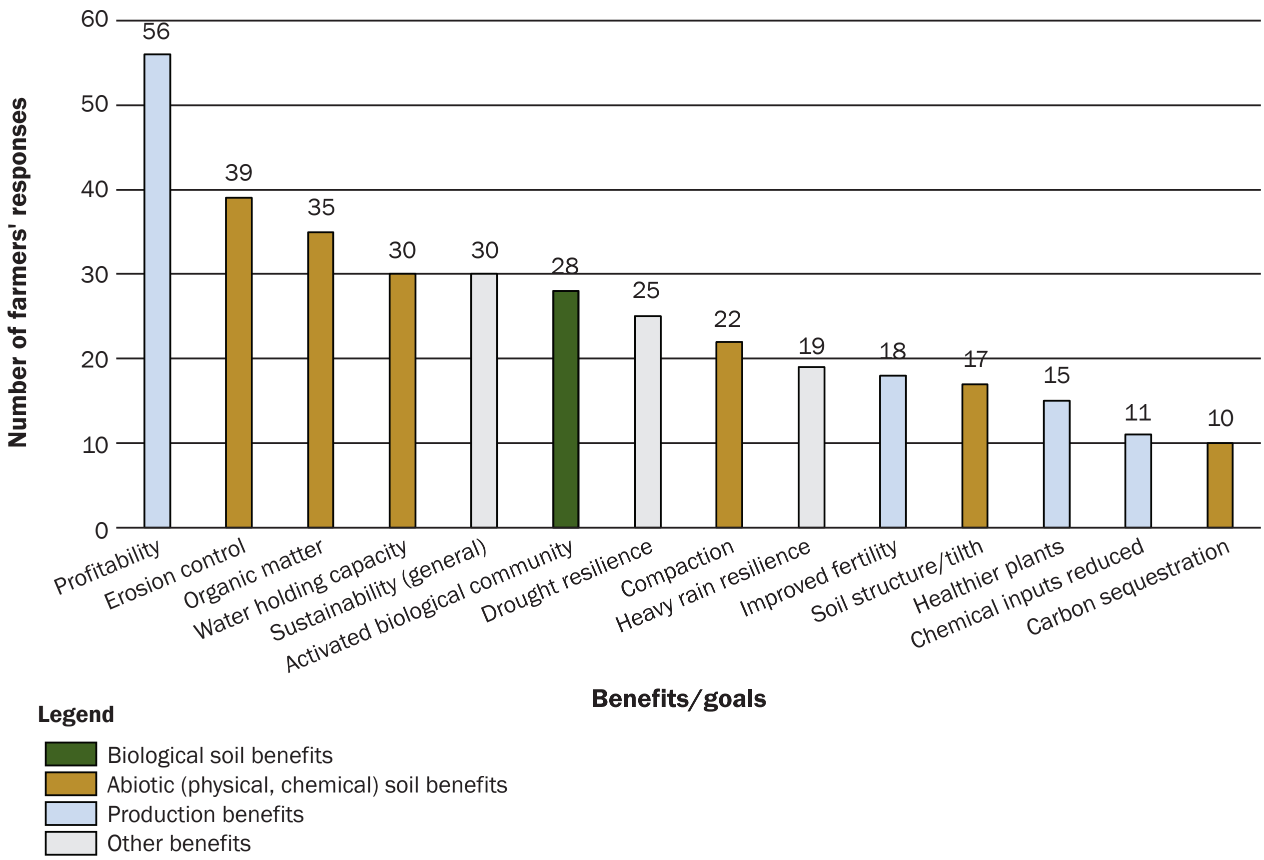


Regarding the abiotic component of SH, organic matter (OM) was the most cited indicator, and the second most cited indicator of SH overall, noted by nearly half of respondents (n = 41; 46%) (figure 1). Additionally, approximately one-third of respondents described SH in terms of overall soil structure/tilth (n = 27; 30%), and drainage (n = 24; 27%), both of which are associated with the abiotic component of SH. Various other physical and chemical indicators of SH were identified by approximately 20% of respondents (e.g., minimized compaction, erosion control, and water holding capacity).

In addition to conceptualizing SH in terms of its biotic and abiotic components, many farmers also conceived of SH explicitly in terms of management practices that they use to promote SH (figure 1, visualized in yellow). For example, the third and fourth most-commonly cited indicators of SH were fertility maintenance (n = 31; 34%) and using cover crops/having a living root year-round (n = 28, 31%). Collectively, approximately two-thirds (n = 59; 66%) of farmers identified at least one management practice as an indicator of healthy soil (figure 1). A select few farmers also enumerated indicators of SH related to other specific management or outcomes-based metrics (e.g., application of manure or biologicals, increased resilience, reduction in weed/pest pressure, etc.). This illustrates that farmers often conceive of SH from a management standpoint, describing SH indictors in terms of the actions they take that target underlying biotic or abiotic components of soil; this also suggests that many farmers view themselves as active participants in SH outcomes and that they believe their management choices are indicators of positive SH outcomes.

Farmers' Perceived Benefits of Healthy Soil. Farmers expressed a variety of goals or perceived benefits (used interchangeably hereafter) they derive from healthy soil. Of the 89 farmers who indicated that SH was valuable or important in some way, 21 goals were identified, 14 of which were identified by at least 10 respondents (figure 3; table S3). On average, farmers identified four benefits of healthy soil, although the number of benefits identified per farmer ranged from 1 to 11. In general, dryland farmers were more likely than irrigating farmers to perceive benefits of healthy soil, across all benefit categories (table 1). Categorically, production-related benefits and those associated with improvements in abiotic components of SH were overwhelmingly the most widely cited benefits by all

Figure 3
Farmers' self-reported perceived benefits of soil health or goals of healthy soil.



farmers, irrespective of irrigation or dryland farming practice (table 1).

Profitability (either stated explicitly or referenced implicitly as better yields or reduced input costs) was cited by nearly two-thirds of respondents (n = 56; 63%) as a core benefit of improved SH, while improvements in various abiotic characteristics of soil, including erosion control (n = 39; 44%), increased OM (n = 45; 51%), and better water holding capacity (n = 30; 34%) were cited by over one-third of respondents. In addition to these reported benefits, nearly one-third of respondents indicated that improvements to the soil biological community were also an important goal of SH (n = 27; 30%).

Table 1
Midwestern farmers' perceived benefits/goals of soil health, by category.

	Irrigating farmers (n = 30)		Dryland farmers (n = 59)		Total farmers (n = 89)	
Benefits, by category	**#**	**%**	**#**	**%**	**#**	**%**
Production-related benefits	25	83	52	88	77	87
Abiotic (physical and chemical) soil benefits	20	67	52	88	72	81
Other benefits	12	40	30	51	42	47
Biological benefits	7	23	20	34	27	30

While cited by comparatively few interviewees, farmers also identified a variety of SH benefits that are relevant to climate change adaptation and mitigation. Considering extreme weather conditions, over one-fifth of farmers noted that SH improved resilience in drought conditions (n = 25; 28%) and heavy rains (n = 19; 21%), while other farmers identified carbon (C) sequestration benefits of SH (n = 10; 11%). Two farmers who used irrigation also noted that SH reduces their reliance on irrigation, and a small number of farmers (n = 4) also noted pride as a benefit they derive from having healthy soil on their farm. Nearly one-third of farmers (n = 27; 30%) commented on production and sustainability related benefits that they hope to derive from SH management, which suggests SH management is increasingly seen as a "win-win" by farmers. For instance,

> Largely when we started off on this pathway [to build soil health], it was long-term profitability of the farm [that motivated us]. If we can reduce production expenses

> as much as possible, if we can maximize economic return year in year out, mitigate the impact of weather on the system… [But what are the main goals of building soil health on my farm?] That's a question without easy answers. I would say a combination of things. Resiliency is certainly one of them. The ability to mitigate weather extremes, whether that's droughts or floods; to facilitate crop production without an abundance of artificial inputs, whether that's herbicides, whether that's fertilizers, fungicides, anything like that. And to some extent too, is controlling environmental losses, whether it's soil erosion, nutrient losses, things like that. (MID005)

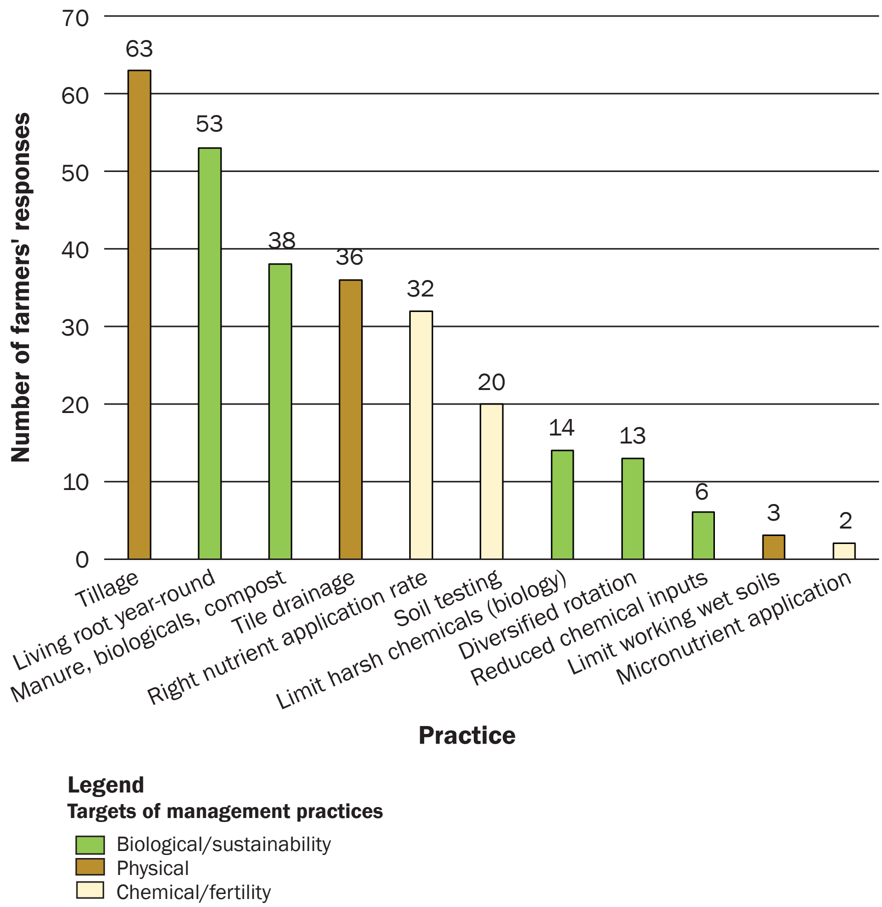
This aligns with the common selling point for many best management practices (BMPs) (Yoder et al. 2021). Indeed, that multiple farmers elaborated on this relationship may be particularly telling as it potentially indicates that sustainability and production are often an assumed or normalized positive relationship for farmers when it comes to SH.

Managing for Soil Health. Across the 91 respondents, nearly all farmers reported that they are working to build SH on their farm (*n* = 86; 95%). Among those who were actively managing for SH, farmers identified 11 management practices by which they actively promote SH (figure 4; table S4). On average, farmers reported using a combination of three SH management practices, although some individuals used as many as eight. The identified management practices can be more broadly categorized as those that target the physical properties, chemical fertility, or biological/sustainability components of SH. Of these domains, physical and biological were the most widespread management areas cited by farmers, with 74 and 73 farmers reporting that they used at least one practice in each category, respectively (81%; 80%); management practices oriented toward chemical aspects of SH were cited less than half as frequently (*n* = 39; 43%), although one-third of farmers noted the importance of appropriate nutrient application (*n* = 32; 35%) as a means to manage for SH on their farm.

Of those farmers who reported they were not actively building SH on their farm, one individual indicated that SH was "probably not a focus of their farm management" (IND019) at all, while others indicated that

Figure 4

Farmer-identified management practices they perceive as promoting soil health.



SH was not a focus of their management because their soils were already healthy or could not be further improved by management actions: "Well, fortunately in this area, we're probably blessed with some of the best land there is. High fertility and everything in it" (ILD007).

Of those management practices that target physical SH components, tillage (*n* = 63; 69%) and tile drainage were the most frequently used, whereas for biologically oriented management practices, keeping a living root year-round (*n* = 53; 58%) and application of manure or biologicals (*n* = 38; 42%) were most frequently cited. Together, these four practices (tillage, living root year-round, manure, and tile drainage, respectively) were the leading ways by which farmers reported promoting SH on their farms. Notably, only approximately one-fifth of farmers (*n* = 21; 23%) described their SH management practices in such a way that all three key dimensions of SH (physical, biological, and chemical) were accounted for (not shown in figure 4).

Overall, tillage was the most widespread practice that farmers associated with SH management (*n* = 63; 69%). Use of tillage was reported twice as often as the next physical-oriented SH practice, tile drainage (*n* = 36; 40%). However, within tillage type respondents had divergent opinions regarding what method best achieves desirable SH outcomes. Nearly three-quarters of farmers who cited tillage as a SH management tool practiced a form of no-tillage or reduced tillage (*n* = 65; 71%). For example, a proponent of the no-tillage management approach explained that,

> We've been doing [no-till for] quite a while now, so there's a lot of [earthworm] burrows out there from them. So I don't feel that we need to be doing the deep tillage the farm dealers promote, because the worms are doing the work. And you

> can see the proof of that when you pull a corn plant out of the ground sometimes. (ILD010)

Yet other farmers who were proponents of deeper tillage also justified their practices because of the perceived benefits to their farm. One farmer, in explaining why he used deeper tillage on his farm, described its importance by contrasting it to both moldboard plowing and no-tillage systems, stating that:

> [Moldboard plowing used to contribute to] wind and water erosion. No question. You know, that's the main issue [with tillage], but yet still some tillage to break up the soil, add oxygenation, porosity, help with water infiltration [is necessary]. If we do some deep ripping, which is very rare, that gets rid of the old plow plans that are down there. It's kinda the best of all the worlds. It stops the erosion and the concerns about that from moldboard plowing, but it addresses the heating up in the spring, the drying out in the spring, that no-till has a problem within our soil type. There are soil types that are fantastically suited for no-till, but [our] farms are not that way. (ILD008)

Farmers' convictions that their tillage practices promote SH, regardless of tillage type, suggests that farmers perceive their management actions as beneficial to SH regardless of measurable SH outcomes, and that the belief in one's management practices is often used as a circular justification to maintain their management approach.

In addition to tillage, keeping a living root growing in the soil year-round was the second most cited management practice used by farmers (n = 53; 58%), and the leading management practice within the biological/sustainability-oriented domain of practices that farmers identified. In comparison, biological-oriented management practices such as limiting the use of harsh chemicals, using a diversified rotation, and reducing overall chemical inputs were reported by less than 15% of farmers (n = 14; 13; and 6; respectively). One particularly environmentally conscious farmer noted that while a primary focus of his farm is productivity, he aims to avoid negative costs to environmental quality, noting that:

> Well, [to promote SH, the] other thing is we don't use harsh, harsh chemicals, because this is not good, in my mind, to the health of the soil, you know, and it's definitely not good for the ecology. (MID006)

The avoidance of harsh chemicals was often noted in reference to anhydrous ammonia, a particularly volatile form of nitrogen (N) fertilizer, which farmers tend to avoid applying given perceptions of its negative impact on SH related biology and leaching potential.

A minor, albeit interesting, point that emerged during interviews was that some farmers used SH as a means to justify practices that the conservation community considers counter to SH promotion and/or the often SH-adjacent desired outcome of reduced environmental harm. For instance, while conservation tillage was primarily the type of tillage associated with SH, a handful of these farmers (n = 6), in addition to two more individuals, indicated that conventional/deep tillage was essential for SH management to address soil compaction (total n = 8; 9%). As was noted above, some farmers emphasized that conventional tillage to promote SH was done on an as-needed basis, rather than as a rule. However, other farmers exclusively practiced conventional tillage and saw this as a direct means to promote SH:

> I think sometimes that, because of our tillage, we're probably affecting some of our biological, or soil activity, with tillage because you're disrupting that cycle. But on the same hand, everybody talks about, "Well, you should be doing no-till and you'd be conserving that." Well, compaction is some of our issues here, so then they certainly offset each other. So, that's the part of... All of them are probably our limiting barriers [to building soil health]. (MII006)

Tile drainage was also reported by many farmers as a means by which they promote SH on their farms. Tile drainage is commonly linked to negative environmental impacts associated with nutrient runoff and water quality degradation (Smith et al. 2015), though farmers emphasized its importance in facilitating beneficial SH properties. For instance:

> I think [tile drainage] probably is… helpful for the soil health that we were talking about. The water in soil kills all the aerobic bacteria and then you're down to your anaerobic bacteria. It's kind of hard on some of those organisms that we're trying to cultivate. (IND002)

As this suggests, farmers occasionally had positive associations toward practices that conservation science considers detrimental to SH or that increase potential harm to surrounding ecosystems (e.g., tile drainage).

Discussion. The farmers we interviewed were widely aware of and generally supportive of building SH on their farms. This finding is reflected in other recent studies of farmers' relationships with SH and together this research continues to generally affirm that US farmers are widely aware of SH and value it as an outcome of farm management (Arbuckle 2017; Bagnall et al. 2020; Wade et al. 2021). Relying on the unique depth of qualitative interviews, our work adds to this body of evidence by revealing that at least a small minority of farmers may be in favor of and actively promoting SH on their farms, but not necessarily conceptualizing this behavior under the title of "soil health." Specifically, several farmers we spoke with voiced strong support for SH only after the concept was described to them. This may be a product of the long-term effort of conservation organizations, such as the NRCS, to promote the properties of healthy soil, but also the ever-evolving titles ascribed to the outcome, including "soil fertility," "soil quality," and more recent efforts to encourage "regenerative" farming practices (Baveye 2020). In terms of doing future research on the topic and conducting engagement/outreach around SH, this finding suggests that "soil health" as a concept will resonate with most farmers, but a minority may benefit from clearly articulating what SH means and potentially also describing how SH relates to these earlier used SH concepts (e.g., "soil quality") to evoke the greatest amount of awareness as possible among diverse farmer audiences.

While awareness of and support for SH was nearly a consensus amongst our interviewees, a diversity of views emerged as we continued to explore how farmers defined and interpreted SH. As we noted above, soils are complex systems comprised of physical, chemical, and biological components (Moebius-Clune et al. 2016), and SH is dependent upon the interaction of these components. Past research with Texas farmers suggests that farmers can identify a wide range of indicators for the physical, chemical, and biological components of SH (Bagnall et al. 2020). Our research affirms that farmers recognize a diverse range of SH indicators, and builds on this by identifying that the majority of farmers place emphasis on biological activity as the primary indicator of SH. This result suggests a degree of nuance to farmers' thinking around SH that has not been previously acknowledged and speaks to the opportunity to further engage farmers in managing soil as an ecosystem.

At the same time, we, like others (Bagnall et al. 2020), recognize that farmers often described indicators of SH in very practical, outcome-oriented terms. Bagnall and colleagues, among other earlier studies, found that farmers consider SH as manifest in productive (i.e., high yielding) soils and/or used qualitative terminology (e.g., compacted versus not, well drained, or mucky) (Ingram et al. 2010; Romig et al. 1995; Karlen et al. 1997). Our farmers widely used qualitative terms to describe SH indicators, and often referred to the practices that promote SH as indicators of SH in and of themselves. While these assessments of SH are certainly not as rigorous as quantitative SH metrics and the tests that produce them, we also do not take them to be a sign of farmers' ignorance. Rather, they point to how farmers translate and assess scientific concepts based on their lived experiences (Ingram et al. 2010; Reimer et al. 2012), and potentially the limited time for strict evaluations of nonessential field metrics given complex, emergent decision parameters (Reimer et al. 2020). Much research has been done on where farmers seek information (Witzling et al. 2021; Bressler et al. 2021; Chen and Shaw 2022; Houser et al. 2019) and the views of these advisor groups on a range of issues, including SH (Wirth-Murray and Basche 2020). Our findings speak to how these groups can maximize the impact of their communication efforts with farmers about SH and other topics. Our finding that farmers tend to balance complex interpretations of soil processes with practical, experiential knowledge about these processes suggests the opportunity to leverage farmers' practical language to enhance communication between farmers and nonfarmers when conducting conservation outreach and engagement. In other words, we propose that effective engagement around SH and other complex processes depends first on meeting farmers where they are by using their language. From there, efforts can be made to continue to advance an understanding of the true complexity of ecological systems at varying scales, which our data suggest many farmers are willing to consider. Ultimately, efforts to more fully advance farmers' understanding of complex system processes like SH can empower them to undertake more independent, systematic decision-making in their management, which can promote environmental awareness and potentially more efficient management (Ballew et al. 2019; Reimer et al. 2020).

The practices used to promote SH (e.g., cover crops and no till) and related environmental outcomes are widely framed as "win-win" opportunities to reduce agricultural pollution while increasing profitability/production resilience (Basche and DeLonge 2017; Yoder et al. 2021; Roesch-McNally et al. 2018a). Among farmers we interviewed, SH was often seen to have these win-win outcomes, with numerous farmers emphasizing that they saw production and environmentally related co-benefits. This finding, like others before, speaks to the success of SH-related outreach and communication—farmers, at least those we interviewed, appear to be hearing and internalizing the "win-win" messaging around SH.

That said, farmers tended to prioritize production as their main SH outcome of interest, and when farmers expressed doubt about SH, it usually came in terms of skepticism that there were clear production- and profit-related benefits to SH. This is ultimately not surprising, but still informative. That farmers' decisions are motivated by, or at the very least frequently constrained by system-level economic imperatives to achieve production and profitability is an increasingly well-documented process (Beethem 2021; Stuart and Schewe 2016; Stuart et al. 2012; Levins and Cochrane 1996). More specifically, research has shown that these factors limit or discourage farmers' use of SH related practices (Houser and Stuart 2020; Roesch-McNally et al. 2018b). Farmers' supportive beliefs about SH's impact on production is then an essential aspect of their adoption of SH practices, given that the agricultural economy demands farmers prioritize this outcome.

Our results reveal that farmers identify a multitude of practices they use to achieve the desirable outcomes associated with SH. On average, farmers reported using three practices toward achieving healthier soils at the aggregated or cross-state level. The simultaneous adoption of multiple conservation practices has widely been shown to be key in effectively achieving environmental outcomes, as compared to single practice adoption (Bosch et al. 2013; McLellan et al. 2018). To date few social science studies have considered the drivers of multiple, simultaneous practices (Denny et al. 2019; Rudnick et al. 2021). Our findings clearly suggest that farmers are conceptualizing multiple practices as related to achieving the key, larger outcome goal of SH. Future SH-related research may benefit from continuing to understand what encourages farmers to become interested in and ultimately adopt sets of SH practices.

Unsurprisingly, tillage was the primary practice farmers reported using to achieve SH. Reduced or no-tillage are, relative to other conservation practices, widely used by midwestern farmers (Claassen et al. 2018). However, what was clear is that not all farmers saw such tillage practices as an absolute path toward improved SH. Instead, some farmers emphasized that conventional tillage approaches were indeed key to achieve SH, with some farmers noting this as an occasional practice, and others noting it as their typical approach. There is some evidence from the ecological literature that occasionally "deep" tillage may indeed promote SH (Bockheim and Hartem 2013). However, continuous conventional tillage approaches are generally not seen as a means to promote SH. Why did some farmers use *more* tillage to achieve SH? Ultimately, the question is beyond the scope of this paper, though our results do suggest a need to further explore how farmers manage for SH and what drives these decisions.

More troubling is that a substantial portion of our farmers who used tile drainage felt it promoted SH. While a well-drained soil is good for crop production and was cited as an indicator of SH by many farmers, tile drainage increases nutrient loss to local waterways (Randall and Gross 2008; Smith et al. 2015). Given that SH is generally promoted to achieve improved environmental outcomes, tile drainage's use toward this end is at least somewhat counterproductive to the ultimate goal of SH promotion for conservation efforts. How widespread is this thinking related to SH and tile drainage (among other potential practices counter to conservation)? Questions like this should be thoroughly considered in future research. At this time, our research suggests the need for more critical attention to how farmers view and understand SH and SH practices—and how we can use this research to encourage the sustainable pursuit of SH.

Summary and Conclusions

Our study offers a detailed depiction of farmers' relationship with the concept of SH as it manifests on their farms and through their practices. By drawing on a relatively large number of qualitative interviews, our results reveal a uniquely grounded take on midwestern row crop farmers' views of SH, the indicators they use to assess SH on their land, what benefits they seek to derive from improving SH, and the management practices they associate with promoting healthier soils.

We undertook this work under the thesis that more research was needed to provide an in-depth perspective on how farmers view, value, and pursue SH given consistent findings that agricultural organizations often misperceive their population's views on these topics. Our results offer a unique level of depth regarding farmers' views on SH and point to the opportunity to refine communication efforts around SH. More broadly, our study clearly suggests that agricultural organizations should feel increasingly confident that many midwestern farmers are familiar with and supportive of SH. Future work must continue to refine our understanding of farmers' relationships with SH, especially given that midwestern farmers largely value SH as an end, but only a minority consistently use key SH-promoting management practices. Continued interdisciplinary research in conjunction with more effective policy and engagement is needed to address these persistent challenges in our agro-food system.

Supplemental Material

The supplementary material for this article is available in the online journal at https://doi.org/10.2489/jswc.2023.00058.

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References

Angel, J.R., C. Swanson, B. Mayes Boustead, K. Conlon, K.R. Hall, J.L. Jorns, K.E. Kunkel, et al. 2018. Chapter 21: Midwest. *In* Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II. Washington, DC: US Global Change Research Program. doi:10.7930/nca4.2018.ch21.

Arbuckle, J.G. 2016. Iowa Farm and Rural Life Poll: 2015 Summary Report. Ames, IA: Iowa State University.

Arbuckle, J.G. 2017. Iowa Farm and Rural Life Poll: 2017 Summary Report. Ames, IA: Iowa State University.

Bagnall, D.K., W.A. McIntosh, C.L.S. Morgan, R.T. Woodward, M. Cisneros, M. Black, E.M. Kiella, and S. Ale. 2020. Farmers' insights on soil health indicators and adoption. Agrosystems, Geosciences & Environment 3(1):e20066. doi:10.1002/agg2.20066.

Ballew, M.T., M.H. Goldberg, S.A. Rosenthal, A. Gustafson, and A. Leiserowitz. 2019. Systems thinking as a pathway to global warming beliefs and attitudes through an ecological worldview. Proceedings of the National Academy of Sciences 116(17):8214-8219.

Basche, A., and M. DeLonge. 2017. The impact of continuous living cover on soil hydrologic properties: A meta-analysis. Soil Science Society of America Journal 81(5):1179–90. doi:10.2136/sssaj2017.03.0077.

Basso, B., J.W. Jones, J. Antle, R.A. Martinez-Feria, and B. Verma. 2021. Enabling circularity in grain production systems with novel technologies and policy. Agricultural Systems 193:103244. doi:10.1016/j.agsy.2021.103244.

Baveye, P.C. 2020. Bypass and hyperbole in soil research: Worrisome practices critically reviewed through examples. European Journal of Soil Science 72(1):1–20. doi:10.1111/ejss.12941.

Beethem, K.K. 2021. Agricultural adaptation, mitigation, and constrained choices: Evidence from the U.S. Midwest. PhD dissertation, Department of Sociology, Michigan State University. https://www.proquest.com/docview/2620751931?pq-origsite=gscholar&fromopenview=true.

Bockheim, J.G., and A.E. Hartemink. 2013. Soils with fragipans in the USA. CATENA 104:233–42. doi:10.1016/j.catena.2012.11.014.

Bosch, N.S., J.D. Allan, J.P. Selegean, and D. Scavia. 2013. Scenario-testing of agricultural best management practices in Lake Erie watersheds. Journal of Great Lakes Research 39(3):429–36. doi:10.1016/j.jglr.2013.06.004.

Bressler, A., M. Plumhoff, L. Hoey, and J. Blesh. 2021. Cover crop champions: Linking strategic communication approaches with farmer networks to support cover crop adoption. Society and Natural Resources 34(12):1602–19. doi:10.1080/08941920.2021.1980165.

Campbell, B.M., D.J. Beare, E.M. Bennett, J.M. Hall-Spencer, J.S.I. Ingram, F. Jaramillo, R. Ortiz, N. Ramankutty, J.A. Sayer, and D. Shindell. 2017. Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecology and Society 22(4). doi:10.5751/ES-09595-220408.

Chen, K., and B. Shaw. 2022. Public communication of soil conservation practices: A large-scale content analysis of Wisconsin's agricultural trade publications. Journal of Soil and Water Conservation 77(2):184–97. doi:10.2489/jswc.2022.00167.

Claassen, R., M. Bowman, J. McFadden, D. Smith, and S. Wallander. 2018. Tillage Intensity and Conservation Cropping in the United States, EIB-197. Washington, DC: USDA Economic Research Service.

Coyne, M.S., E.M. Pena-Yewtukhiw, J.H. Grove, A.C. Sant'Anna, and D. Mata-Padrino. 2022. Soil health – It's not all biology. Soil Security 6:100051.

David, M.B., L.E. Drinkwater, and G.F. McIsaac. 2010. Sources of nitrate yields in the Mississippi River basin. Journal of Environmental Quality 39(5):1657–67. doi:10.2134/jeq2010.0115.

Denny, R.C.H., S.T. Marquart-Pyatt, and M. Houser. 2019. Understanding the past and present and predicting the future: Farmers' use of multiple nutrient Best Management Practices in the Upper Midwest. Society and Natural Resources 32(7):807–26. doi:10.1080/08941920.2019.1574045.

Doll, J.E., B. Petersen, and C. Bode. 2017. Skeptical but adapting: What midwestern farmers say about climate change. Weather, Climate, and Society 9(4):739–51. doi:10.1175/WCAS-D-16-0110.1.

Houser, M., S.T. Marquart-Pyatt, R.C.H. Denny, A. Reimer, and D. Stuart. 2019. Farmers, information, and nutrient management in the US Midwest. Journal of Soil and Water Conservation 74(3):269–80. doi:10.2489/jswc.74.3.269.

Houser, M., and D. Stuart. 2020. An accelerating treadmill and an overlooked contradiction in industrial agriculture: Climate change and nitrogen fertilizer. Journal of Agrarian Change 20(2):215–37. doi:10.1111/joac.12341.

Ingram, J., P. Fry, and A. Mathieu. 2010. Revealing different understandings of soil held by scientists and farmers in the context of soil protection and management. Land Use Policy 27(1):51–60. doi:10.1016/j.landusepol.2008.07.005.

Jacobson, L.M., M.B. David, and L.E. Drinkwater. 2011. A spatial analysis of phosphorus in the Mississippi River basin. Journal of Environment Quality 40(3):931. doi:10.2134/jeq2010.0386.

Karlen, D.L., N.J. Goeser, K.S. Veum, and M.A. Yost. 2017. On-farm soil health evaluations: Challenges and opportunities. Journal of Soil and Water Conservation 72(2):26A−31A. doi:10.2489/jswc.72.2.26A.

Karlen, D.L., M.J. Mausbach, J.W. Doran, R.G. Cline, R.F. Harris, and G.E. Schuman. 1997. Soil quality: A concept, definition, and framework for evaluation (a guest editorial). Soil Science Society of America Journal 61(1):4-10.

Lehman, R., C. Cambardella, D. Stott, V. Acosta-Martinez, D. Manter, J. Buyer, J. Maul, J. Smith, H.P. Collins, J.J. Halvorson, R.J. Kremer, J.G. Lundgren, T.F. Ducey, V.L. Jin, and D.L. Karlen. 2015. Understanding and enhancing soil biological health: The solution for reversing soil degradation. Sustainability 7(1):988–1027. doi:10.3390/su7010988.

Levins, R.A., and W.W. Cochrane. 1996. The treadmill revisited. Land Economics 72(4):550. doi:10.2307/3146915.

Marquart-Pyatt, S. 2022. Panel Farmer Survey: 2017-2022. Kellogg Biological Station (KBS) KBS Long Term Ecological Research (LTER). Unpublished data. East Lansing, MI: Michigan State University. https://lter.kbs.msu.edu/.

Matson, P.A., W.J. Parton, A.G. Power, and M.J. Swift. 1997. Agricultural intensification and ecosystem properties. Science 277(5325):504-509.

McLellan, E.L., K.G. Cassman, A.J. Eagle, P.B. Woodbury, S. Sela, C. Tonitto, R.D. Marjerison, and H.M. van Es. 2018. The nitrogen balancing act: Tracking the environmental performance of food production. BioScience 68(3):194–203.

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M. Kurtz, D.W. Wolfe, and G.S. Abawi. 2016. Comprehensive Assessment of Soil Health—The Cornell Framework, 3.2 edition. Geneva, NY: Cornell University.

Montanarella, L. 2015. Agricultural policy: Govern our soils. Nature 528:32–33. doi:10.1038/528032a.

Morgan, C., and S. Cappellazzi. 2021. Assessing soil health: Putting it all together. Crops and Soils 54(4):64–68. doi:10.1002/crso.20125.

Prokopy, L.S. 2011. Agricultural human dimensions research: The role of qualitative research methods. Journal of Soil and Water Conservation 66(1):9A-12A. doi.org/10.2489/jswc.66.1.9A.

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):520–34. doi:10.2489/jswc.74.5.520.

Randall, G.W., and M.J. Goss. 2008. Nitrate losses to surface water through subsurface, tile drainage. In Nitrogen in the Environment, 145-175. Cambridge, MA: Academic Press.

Reimer, A.P., M.K. Houser, and S.T. Marquart-Pyatt. 2020. Farming decisions in a complex and uncertain world: Nitrogen management in midwestern corn agriculture. Journal of Soil and Water Conservation 75(5):617-628. doi.org/10.2489/jswc.2020.00070.

Reimer, A.P., A.W. Thompson, and L.S. Prokopy. 2012. The multi-dimensional nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. Agriculture and Human Values 29(1):29–40. doi:10.1007/s10460-011-9308-z.

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. doi:10.2489/jswc.69.2.57A.

Roesch-McNally, G.E., J.G. Arbuckle, and J.C. Tyndall. 2018a. Barriers to implementing climate resilient agricultural strategies: The case of crop diversification in the US Corn Belt. Global Environmental Change 48:206-215.

Roesch-McNally, G.E., J.G. Arbuckle, and J.C. Tyndall. 2018b. Soil as social-ecological feedback: Examining the "ethic" of soil stewardship among Corn Belt farmers. Rural Sociology 83(1):145-173.

Roesch-McNally, G.E., A.D. Basche, J.G. Arbuckle, J.C. Tyndall, F.E. Miguez, T. Bowman, and R. Clay. 2018c. The trouble with cover crops: Farmers' experiences with overcoming barriers to adoption. Renewable Agriculture and Food Systems 33(4):322–33. doi:10.1017/S1742170517000096.

Rogers, E.M. 2003. Diffusion of Innovations, 5th edition. New York, NY: Free Press.

Romig, D.E., M.J. Garlynd, R.F. Harris, and K. McSweeney. 1995. How farmers assess soil health and quality. Journal of Soil and Water Conservation 50(3):229-236.

Rudnick, J., M. Lubell, S.D.S. Khalsa, S. Tatge, L. Wood, M. Sears, and P.H. Brown. 2021. A farm systems approach to the adoption of sustainable nitrogen management practices in California. Agriculture and Human Values 38(3):783–801. doi:10.1007/s10460-021-10190-5.

Saldaña, J.M. 2016. The Coding Manual for Qualitative Researchers, 3rd edition. London, England: SAGE Publications.

Smith, D.R., K.W. King, L. Johnson, W. Francesconi, P. Richards, D. Baker, and A.N. Sharpley. 2015. Surface runoff and tile drainage transport of phosphorus in the midwestern United States. Journal of Environment Quality 44(2):495. doi:10.2134/jeq2014.04.0176.

Soil Health Institute. 2019. Soil health policy resources. Morrisville, NC: Soil health Institute. https://soilhealthinstitute.org/resources/catalog.

Stewart, R.D., J. Jian, A.J. Gyawali, W.E. Thomason, B.D. Badgley, M.S. Reiter, and M.S. Strickland. 2018. What we talk about when we talk about soil health. Agricultural and Environmental Letters 3(1):180033. doi:10.2134/ael2018.06.0033.

Stuart, D., and R.L Schewe. 2016. Constrained choice and climate change mitigation in US agriculture: Structural barriers to a climate change ethic. Journal of Agricultural and Environmental Ethics 29(3):369-385.

Stuart, D., R.L. Schewe, and M. McDermott. 2012. Responding to climate change. Organization and Environment 25(3):308–27. doi:10.1177/1086026612456536.

Thaler, E.A., I.J. Larsen, and Q. Yu. 2021. The extent of soil loss across the US Corn Belt. Proceedings of the National Academy of Sciences 118(8):e1922375118. doi:10.1073/pnas.1922375118.

USDA NRCS (Natural Resources Conservation Service). 2012. Healthy Soil for Life. Washington, DC: USDA NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/.

USDA NASS (National Agricultural Statistical Service). 2021. Crop Production 2021 Summary. Washington, DC: USDA NASS. https://www.nass.usda.gov/Statistics_by_State/index.php.

USGCRP (US Global Change Research Program). 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II, ed. D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart. Washington, DC: US Global Change Research Program. doi:10.7930/NCA4.2018.

Wade, J., M.A. Beetstra, M.L. Hamilton, S.W. Culman, and A.J. Margenot. 2021. Soil health conceptualization differs across key stakeholder groups in the Midwest. Journal of Soil and Water Conservation 76(6):527–33. doi:10.2489/jswc.2021.02158.

Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, et al. 2013. Climate Change and Agriculture in the United States: Effects and Adaptation. USDA Technical Bulletin 1935. Washington, DC: USDA. https://www.usda.gov/sites/default/files/documents/CC%20and%20Agriculture%20Report%20(02-04-2013)b.pdf.

Wander, M.M., L.J. Cihacek, M. Coyne, R.A. Drijber, J.M. Grossman, J.L.M. Gutknecht, W.R. Horwath, S. Jagadamma, D.C. Olk, M. Ruark, S.S. Snapp, L.K. Tiemann, R. Weil, and R.F. Turco. 2019. Developments in agricultural soil quality and health: Reflections by the Research Committee on Soil Organic Matter Management. Frontiers in Environmental Science 7. https://doi.org/10.3389/fenvs.2019.00109.

Wirth-Murray, M., and A. Basche. 2020. Stimulating soil health within Nebraska's Natural Resources Districts. Journal of Soil and Water Conservation 75(4):88A-93A. doi:10.2489/jswc.2020.0512a.

Witzling, L., D. Wald, and E. Williams. 2021. Communicating with farmers about conservation practices: Lessons learned from a systematic review of survey studies. Journal of Soil and Water Conservation 76(5):424–34. doi:10.2489/jswc.2021.00145.

Yang, T., K.H.M. Siddique, and K. Liu. 2020. Cropping systems in agriculture and their impact on soil health—A review. Global Ecology and Conservation 23:e01118. doi:10.1016/j.gecco.2020.e01118.

Yoder, L., M. Houser, A. Bruce, A. Sullivan, and J. Farmer. 2021. Are climate risks encouraging cover crop adoption among farmers in the Southern Wabash River Basin? Land Use Policy 102:105268. doi:10.1016/j.landusepol.2020.105268.