Examining Soil Health Perceptions:

Identifying barriers to adoption, characterizing resource needs, and defining soil health

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Introduction

During the past century, maximizing agricultural production and profitability, especially in row-crop agriculture, has centered on technological innovations – improving genetics for disease and insect resistance, herbicide-tolerance, drought and heat tolerance, and higher yields. Traditional yet important agricultural methods, such as building and caring for soil, have gotten less attention. For some farmers, this trend has reduced their long-term sustainability by exacerbating problems such as herbicide resistant weeds, soil erosion, nutrient loss, and yield losses from drought and flooding. Improving soil health can help meet surface and ground water quality goals, reduce soil erosion, build soil resiliency and reduce the impacts of climate variability.

Implementing a soil health system in the production of food, fiber, and fuel can dramatically impact not only air and water quality, but improve farm economic sustainability and quality of life in rural areas. Significant research has been conducted to better understand biophysical processes and indicators of soil health, however, there is limited social science research surrounding the topic of soil health. This survey conducted by the Soil Health Nexus team examined how different audiences define soil health, growers' perceived barriers to adopting soil health practices and resource needs for teaching soil health. The results of this survey were used to help inform the Soil Health Nexus' digital Soil Health Toolbox (https://soilhealthnexus.org/resources/) of soil health resources.

Methodology

Data were collected through an online survey of producers, agronomists, agricultural educators, state and federal agency staff, consultants, and soil and water conservation district staff from January to August 2018. The survey aimed to identify the obstacles and challenges encountered by decision-makers (i.e. producers), and farm advisors (i.e. extension educators, state and federal agency staff, retail agronomists, etc.) to adopting practices for improved water quality and soil health, characterize how different audiences define soil health, and assess educator resource needs for delivering soil health trainings and demonstrations.

The sample was distributed throughout the North Central Region of the United States using a snowball sampling technique. The survey was distributed to the Soil Health Nexus team, state soil health officials, and state extension professional networks in the North Central Region cumulating in 294 respondents.

Survey respondents consisted of 30% federal and state agency staff, 27% extension educators, 21% farmers, 12% soil and water conservation district staff, 2% consultants, and 1% non-profit agricultural organization personnel. The sample had the most representation from Nebraska (N=63), Michigan (N=60), Wisconsin (N=52) and Minnesota (N=31), but included responses from all twelve North Central Region states.

Thematic coding was used to analyze open-ended responses. Responses varied greatly in their robustness, however, analysis focused on the topics covered rather than their quality or completeness. One response could be coded into multiple themes depending on the number of topics listed.

Key Findings

Soil Health Implementation

The most used and recommended soil health practices among respondents were crop rotation (81%), no tillage (69%), and cover crop mix (68%), with no tillage being more common with respondents from the western portion of the North Central Region (79% vs 60%) which included Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. Conversely, conservation tillage, or the practice of minimizing the frequency and intensity of tillage, was more popular in eastern portion of the region (50% vs 36%) which comprised of Illinois, Indiana, Ohio, Michigan, and Wisconsin. In total, single species cover crops had a 50% use or recommendation rate, while 43% of respondents utilized or recommended conservation tillage and 27% strip tillage, or the conservation tillage practice of tilling only the seed row of the soil.

Overall, 57% of farmer respondents noted using manure, a practice recommended by roughly 90% of federal and state agency staff and extension educators as improving soil health. The majority of producers using manure reported surface application (87%), however, incorporation was also relatively common (63%). Injection was much less common with only 12% of producers reporting injecting manure into their fields.

Respondents in the western portion of the region reported using dry feedlot manure and liquid swine manure as a nutrient source at the highest rates, while respondents in the eastern portion of the region relied on liquid dairy manure and compost more commonly. Poultry was the least used nutrient source across both portions of the region.

Thematic coding was used to analyze the types of soil health practices respondents noted implementing to improve water quality. Analysis demonstrated that roughly half of the respondents mentioned reducing tillage and cover crop adoption as a key practice they adopted and roughly a third noted implementing some form of vegetative buffers. Approximately a quarter mentioned nutrient management as a key water quality practice implemented, however the type of nutrient reduction practices varied greatly between responses. Surface water and subsurface drainage management practices including grassed waterways and constructed wetlands, irrigation management, contour strips, sediment control basins, two stage ditches, and structures such as terraces or tile were also mentioned somewhat frequently as methods to control flows of water.

Respondents noted that building organic matter, water infiltration, erosion control, nutrient management, and water holding capacity were the five soil health benefits most important to them, however, we see overall, respondents felt a number of benefits were important (Figure 1).

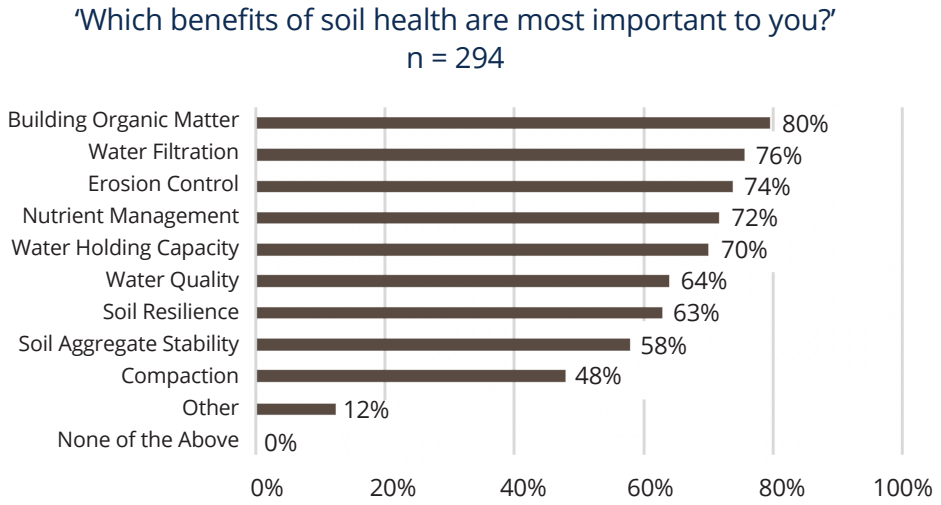

Figure 1. *The soil health benefits most important to respondents.*

Interestingly, there are some variations in the perceived importance of soil health benefits across different audience groups as shown in Table 1. For example, farmers and consultants indicated higher importance to nutrient management compared to state and federal agency staff and extension educators.

	Building Organic Matter	Water Infiltration	Erosion Control	Nutrient Management	Water Holding Capacity	Water Quality	Soil Resiliency	Aggregate Stability	Compaction
Farmers (n= 60)	92%	73%	75%	80%	77%	58%	63%	52%	55%
State and Federal Agency Staff (n=88)	80%	81%	81%	67%	67%	78%	66%	58%	53%
Extension Educators (n=80)	75%	70%	63%	65%	61%	46%	58%	58%	38%
Consultants (n=7)	57%	100%	86%	88%	86%	57%	43%	71%	57%

Table 1. *The soil health benefits most important to respondents broken out by audience*

Defining Soil Health

Respondents were asked how they define soil health and thematic coding was used to identify what respondents felt were the key components of soil health. In total, 210 individuals responded to this question.

Given the broad range of responses, topics identified in the open-ended responses were condensed into 14 themes, which were then broken down into two broad categories. The first category was characteristics of healthy soil and included descriptions of the soil itself, how soil functions, and the physical, biological and chemical properties which contribute to healthy soil. The themes identified in this category include biology, tilth or structure, chemistry, water functionality, organic matter, vitality, interconnectivity and undisturbed. The second category were themes which described the effects of healthy soil or the byproducts of soil health such as productivity, sustaining ecosystems, stability, sustainability and resilience. Definitions and examples of each theme are provided in Table 2.

	Thematic Code	**Category**
Biology	Biology reflects an acknowledgement that microorganisms, insects, and other life make important contributions to maintaining the health of soil. This theme makes explicit note of these contributions but does not necessarily mean the response connected the whole of the soil as a living organism. E.g. *"Feeding and reaping the rewards of the 12 billion or so living organisms 6 inches below every footprint."*	Characteristics of healthy soil
Tilth or Structure	Tilth and structure includes loose terms such as structure, aggregates, moisture, granularity, color, texture and whether the soil was suitable for planting. In general, respondents were often not specific on desirable qualities regarding these characteristics. *E.g. "Porous soil that doesn't erode easily"*	Characteristics of healthy soil
Chemistry	Chemistry was taken to be referring in general to the phosphorus, nitrogen, and other nutrients found in soil. Either the presence of nutrients, including meeting some identified or unidentified standard for content, or functions like cycling nutrients through the soil were identified in this theme. *E.g. "Managing the soil pH and nutrients available for the crops being planted."*	Characteristics of healthy soil
Water Functionality	This theme identifies mentions of water infiltration and water holding capacity primarily, but all mentions of soil and water intermixing in a functional manner were identified in this code. *E.g. "The ability of a soil to allow water to infiltrate, to resist erosion and compaction."*	Characteristics of healthy soil
Organic Matter	Mentions of organic matter content were included in this theme, though responses varied in specifying whether the presence, an increase, or a high-level of organic matter was desirable. *E.g. "Soil with high organic matter and low likelihood of erosion."*	Characteristics of healthy soil
Vitality	Vitality operationalizes the notion that the soil itself is alive and exists as a single unit. Rather than being a host for living things or a medium to support live, the soil itself has its own life and patterns of being. E.g. *"Soil is healthy when all of its inhabitants are thriving together. It is a living ecosystem unto itself. This includes microorganisms, plants, animals, insects, as well as organic compounds, humus, minerals, etc."*	Characteristics of healthy soil
Interconnectivity	Responses which noted the interactive nature of individual items, primarily referring to the physical, chemical, and biological properties of soil being necessary to a truly healthy soil were coded under this term. The mention of interaction had to be relatively explicit in order to receive this code, simply noting both chemical and biological components did not therefore imply they interacted. E.g. *"The optimal combination of nutrients, biology and structure that can maintain and sustain productivity"*	Characteristics of healthy soil

	Thematic Code	Category
Undisturbed	Several responses reflected that healthy soil requires minimal human intervention through chemical inputs or other management strategies or that a healthy soil and environment reflects what it would have been in the absence of human involvement. E.g. *"The ability of the soil to be productive without or with minimal synthetic inputs."*	Characteristics of healthy soil
Productivity	This theme identifies responses that asserted the output of the fields' soil are indicators of its health. This theme emphasizes commercial output as opposed to growth in more natural, non-social settings. E.g. *"The ability of the soil ecosystem to maximize plant growth"*	Effects of healthy soil
Sustains Ecosystems	This theme similarly took the output of the soil to be a significant indicator of health, but with less of an orientation towards human needs. Rather, this theme highlights components and processes of ecosystems existing without human interventions and improving the quality of the surrounding environment, including water, air, and life. Differentiating this theme from vitality is the focus on items outside of the soil rather than what exists in the soil alone. E.g. *"The ability for soil to sustain appropriate vegetation based on geography over time, while playing other vital roles including filtration."*	Effects of healthy soil
Stability	Stability was operationalized separately from structure as many responses framed it in the context of erosion from wind or water. E.g. *"Not losing soil to wind or water erosion."*	Effects of healthy soil
Sustainability	Sustainability touched on the soils' long term viability for future generations in the context of erosion, depletion of nutrients, damaging of biology, or other minor factors which would contribute to disintegration. Unlike sustain ecosystems, which focuses more on soil's current ability to sustain life, sustainability focuses on the long-time horizon. E.g. *"The capacity of the soil to regeneratively sustain life."*	Effects of healthy soil
Resiliency	Resiliency refers to the ability of the soil to return to a healthy state following drought, flood, or other stressful natural events. Artificial events such as cropping pattern adjustments also fit this term. E.g. *"Soil that is resilient to stressful conditions, and able to support healthy plants through those stressors, such as drought, heat, flood, etc. Furthermore, healthy soil supports plants by having healthy and balanced nutrient cycles, and a balanced soil food web that helps suppress pests and disease."*	Effects of healthy soil

Table 2. *Definitions of the 14 thematic codes identified when respondents defined soil health*

When examining all responses, the themes productivity and biology were the most common. Tilth or structure, chemistry and sustaining ecosystems were also mentioned by over a quarter of the respondents.

Examining the patterns in how different audience groups defined soil health, we see key patterns emerge when comparing extension educators, state and federal agency staff and farmers as shown in Table 3.

Results demonstrate that extension educators, and to a lesser extent state and federal agency staff, associate soil health with productivity more often than farmers. Farmers noted the themes biology, chemistry, and tilth/structure at the highest frequency, though it is important to note that nearly a quarter of farmer responses did include the theme productivity.

Overall, we see that while all three audience groups mentioned themes in the characteristics of soil health category at a relatively high rate, extension educators and state and federal agency staff were more likely to mention themes in the effects of healthy soil category. This finding could suggest that farmers are not as likely to recognize the benefits of soil health practices as extension educators and agency staff.

	All Respondents		Extension Educators		State and Federal Agency Staff		Farmers	
N Responded	**210**		**77**		**63**		**49**	
Productivity	40%	84	48%	37	40%	25	25%	12
Biology	39%	81	43%	33	33%	21	50%	22
Tilth/Structure	31%	66	36%	28	30%	19	33%	16
Chemistry	31%	64	31%	24	30%	19	35%	17
Sustain Ecosystems	29%	60	31%	24	44%	28	14%	7
Water Functionality	22%	46	20%	15	22%	14	27%	13
Vitality	19%	40	17%	13	27%	17	16%	8
Organic Matter	17%	35	9%	7	22%	14	22%	11
Sustainability	16%	34	20%	15	19%	12	6%	3
Interconnectivity	12%	25	13%	10	13%	8	14%	7
Stability	11%	22	8%	6	10%	6	16%	8
Undisturbed	9%	18	9%	7	11%	7	2%	1
Resiliency	8%	17	9%	7	10%	6	2%	1

Table 3. *Frequency of themes mentioned when defining soil health overall and broken out by audience*

Barriers to Adoption of Practices to Promote Soil Health

Respondents identified several perceived barriers to implementing soil health practices. Some of the most common barriers related to economic hurdles such as the perceived cost of time and the financial investments needed to obtain new equipment and implement new practices. Respondents also noted concern regarding the effect of new practices on their yields and were hesitant to risk income when crop prices are particularly low. Others indicated they felt there was little or no evidence that these practices improved profits or crop production to balance out increased input costs.

Multiple respondents reported cultural barriers such as resistance from farmers tied to traditional practices. Industry stakeholders with financial interests in maintaining the status quo were also identified as a barrier. Another institutional barrier is the common practice of farmers renting land, rather than owning it, which leaves little to no incentive to implementing soil health practices for long-term social, environmental, or financial benefits.

Other responses suggested that some of the barriers were farm management or environmental in nature such as soil type, crop type, timeliness of planting cover crops in the fall and terminating in the spring, planting in heavy residue, brevity of the growing season, finding the right cover crops, and accessing water and manure.

A final and significant barrier was a lack of knowledge of the importance of soil health, the practices that can be used to improve soil health, or how to implement these practices on the farm.

Resources for Learning

Respondents noted that field days were the most helpful resource for learning about soil health in the past (85%), with half-day workshops (54%) and fact sheets (52%) also proving helpful. Decision support tools (29%), social media (20%), and email discussion groups (18%) were the least helpful respectively. That said, farmers found email discussion groups to be more valuable than other groups with 30% identifying them as helpful, compared to 11% of federal and state agency staff and 16% of extension educators.

Looking to the future, respondents felt field days (75%), webinars (66%), fact sheets (61%), and half-day workshops (55%) would be most helpful in increasing their understanding of soil health, manure and water quality practices. Farmers, as compared to state and federal agency staff and extension educators, more strongly preferred one-on-one consultations and email discussion groups and were less interested in webinars and full day workshops. Open-ended responses indicated that independent reading material such as newsletters or blogs, conferences, and demonstrations were also useful soil health learning materials.

Reaching Farm Audiences

Many responses indicated the most effective way to reach farmers would be to have other farmers share their experiences, rather than state and federal agency staff and extension educators. Several additional tools, resources, and topics were frequently requested by respondents, including research and data on the economic benefits of better soil health practices, data on specific practices such as cover crops and general data on how healthy soil performs comparatively.

There were also substantial requests for instruction and reference information on implementing specific practices, most commonly cover crops but extending to other practices as well. Respondents also requested basic information that might be shared in a classroom setting, for example how water infiltration works,

more information on soil microbiology, and how plants and nutrients interact with the soil, suggesting respondents want to learn more about underlying soil health principles.

Discussion and Future Research Needs

Currently, there is limited social science research surrounding soil health and water quality. This survey, while it does have its limitations, provides key baseline data on the type of practices and goals farmers, government officials, and extension educators are using and pursuing, how different audiences define soil health, barriers to adoption and educator resource needs. It is important to note that this survey, while helpful, is not based on a representative sample and should be treated with caution when generalizing to outside audiences.

The survey does provide several key findings, including:

- Crop rotation, no-tillage and cover crop mixes are the most common soil health practices recommended and used throughout the region.
- Surface application of manure is the most common means of manure application in the field.
- Lack of evidence on the economic benefits of soil health, single-season land rentals, general resistance to change, and management concerns were the biggest barriers noted for soil health practice adoption.
- Respondents noted a lack of information and soil health knowledge and the need for education on implementing certain soil health practices and the benefits those specific practices.
- Extension educators, and to a lesser extent state and federal agency staff, associate soil health with productivity more often than farmers.
- When defining soil health, extension educators and state and federal agency staff were more likely to mention the effects or impacts of healthy soil than farmers.
- Producers are interested in soil health practices that benefit the productivity of their crops, but are concerned with the economic challenges these practices pose.
- Field days continue to be a popular soil health communication channel across audiences.
- Less than 38% of respondents indicated that webinars were helpful in the past, but 66% would like to see more webinars moving forward.
- Producers, unlike other audiences, find email discussion groups helpful in learning and making decisions about soil health.

Future research should investigate the effectiveness of different soil health practices on improving yields as many producers have a valid concern of new practices jeopardizing their financial stability. Moreover, there was also a request for more information on the economic benefit of implementing certain practices, over the choice not to make a practice change.

Results demonstrate that when communicating future research and soil health recommendations, educators should consider hosting field-days, webinars and creating facts sheets. Also, when communicating directly with producers, email discussion groups should be considered as viable communication channels for soil health and water quality information, and the effects or impacts of soil health should be emphasized where possible, as farmers may not be as likely to recognize the benefits of soil health compared to other audience groups.