How farmers assess soil health and quality

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The requirements of agricultural and environmental sustainability have dramatically redefined soil quality. The traditional view of soil quality, as measured by soil performance and productivity, is now considered inadequate for what it does not and cannot reveal. Accordingly, the emerging definition of soil quality extends beyond crop production to issues of food safety, human and animal health, and water quality (Doran and Parkin; Parr et al.).

Concern for soil quality is not limited to agricultural scientists, natural resource managers, and policymakers. Farmers also have a vested interest in soil quality; its stewardship and maintenance have always rested with them. Farmer interest in soil health, a term some farmers prefer to soil quality, may have been encouraged by their desire to examine and validate the management practices they use on their own farm. Evidence of farmer interest shows in the increased attention to soil health in alternative farming publications like *New Farm* and *Acres USA*.

Over the last decade, farmers in traditional farming systems have been credited for their sophisticated knowledge of agroecosystems (Alcorn; Bentley; Thrupp). The working knowledge possessed by these farmers accumulates through experiences in the material world and is attuned to the ecological and social realities of the local environment (Harper; Kloppenburg; Orr; Weinstock). Researchers have articulated that those close to the land have complex folk soil taxonomies (Bellon and Taylor; Williams and Ortiz-Solorio), possess a variety of practical solutions to conserve agricultural resources (Pawluk et al.; Zimmerer), and employ intricate methods to manage soils (Bocco; Hecht; Perrot-Maître and Weaver; Wilken).

In the context of soil quality, farmers primarily attend to the local peculiarities of how best to maintain a soil's health. Alternatively, scientific inquiry is concerned with the definition of soil quality and establishing criteria to quantify its parameters (Doran and Parkin; Larson and Pierce). These different concerns and interests theoretically complement one another, as both parties work toward the goals of productivity and sustainability (Kloppenburg). Chambers promotes farmer and scientist partnership, asserting that, "Combined they may achieve what neither would alone."

To this end, the Wisconsin Soil Health Program has consulted the knowledge and experience of more than 100 Wisconsin producers in order to understand their perspective on soil health and quality. The program has progressed from informal dialogues with farmers (Harris; Harris et al.; Porter), to the development of an interpretive framework that recognizes descriptive and analytical properties of soil and related systems (plants, animals/humans, water, and air) for soil quality assessment (Harris and Bezdicek). This interpretive framework provided the foundation for a coordinated set of tools to gather and analyze farmer knowledge of soil health and quality (Garlynd et al.), and for the development of a soil health scorecard based on farmer knowledge (Romig et al., 1994, 1995).

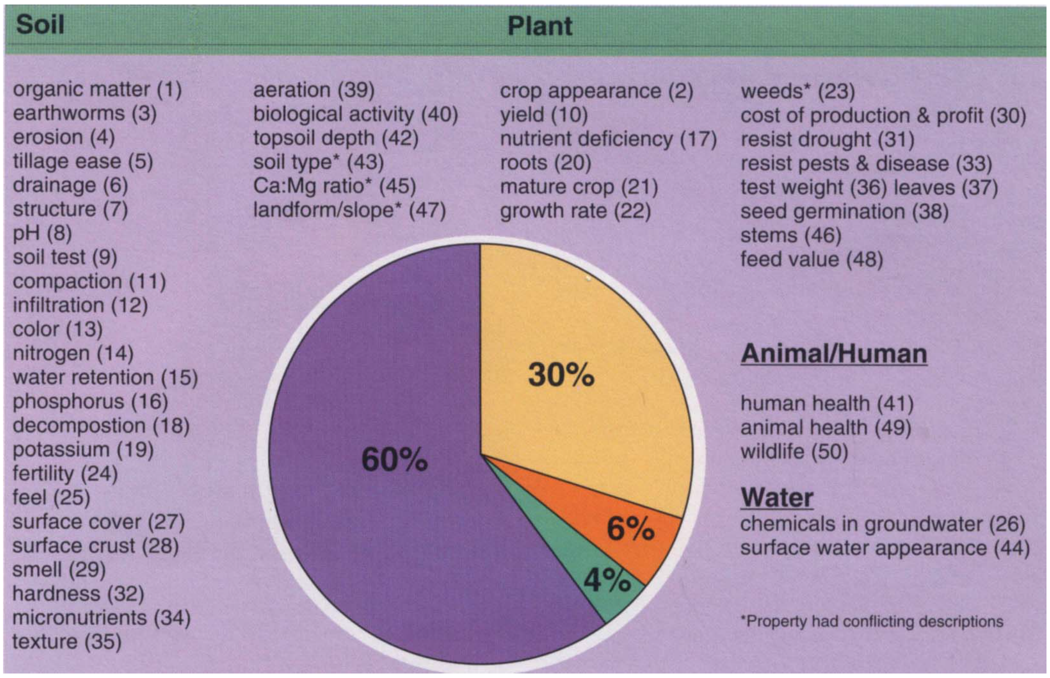
This paper is an overview of our recent work examining the nature of farmers' assessment of soil health. Here we articulate farmers' knowledge of soil health, specifically their priorities and how they are characterized. Furthermore, the potential contribution of farmer knowledge to soil quality research, especially the development of indices for soil quality and health assessment, is discussed.

Soil health interviews

In the summer of 1993, we discussed the broad question "How do you recognize a healthy soil?" during structured interviews with 28 farmers through a series of open- and closed-ended questions. Participants were associated with the University of Wisconsin's integrated cropping systems research in Walworth and Columbia counties in southeast Wisconsin. The farmers operated conventional and low-input cash grain and dairy farms ranging in size from 80 to 2,200 acres. Agricultural soils of the region are commonly formed in silt overlying

photo: Farmers rely primarily on sensory observations to evaluate a soil's health and quality. Healthy soil was often described as having a distinct sweet or earthy smell.

Figure 1: Distribution of top 50 farmer-identified soil health properties placed within their respective systems. Relative rank of property is indicated in parenthesis



glacial till or outwash.

Interviews were coded for 97 soil health properties and a semi-quantitative analysis of the interviews scored each property for frequency, sequence, and percent of farmers who discussed it. Properties were considered greater in importance if they were mentioned earlier in the interview, used more frequently in the interview, and used by a majority of the farmers. A procedure was developed based on these assumptions to rank each attribute relative to one another. The words, phrases, or numerical values that farmers used to characterize soil health properties were also cataloged[1]. The methods used in this study to gather and synthesize farmer knowledge are detailed elsewhere[2].

Farmers' assessment of soil health

Farmer-identified soil health properties. Soil is but one of a variety of resources in a farm enterprise. It therefore follows that farmers may not limit their diagnosis of a soil's health strictly to attributes of the soil. From a farmers perspective, reflections of a soil's health can be seen in plants, animals, and water (ground- and surface) that are both familiar and apparent to farmers. To judge the quality of a soil, farmers integrate chemical, physical/morphological, and biological properties of soils, plants, animals/humans, and water. Figure 1 illustrates the distribution and rank of the top 50 soil health properties as identified by the interview analysis.

Overall, soil attributes took precedence in their mention (60 percent). Farmers placed their emphasis on biological components (organic matter, earthworms, and decomposition), chemical (pH, soil tests, and primary nutrients) and physical (erosion, compaction, and soil-water relationships) properties. Many soil properties identified in Figure 1 are morphological features that describe a soil's physical nature and are common to field descriptions of soils. These included structure, color, hardness (friability), and texture. Farmers frequently addressed properties of the topsoil rather than subsoil features, presumably because topsoil is influenced more by tillage and plant growth.

Attributes of plants figured prominently in farmers' assessment of soil quality. Again, many of the plant properties described morphology features (roots, leaves, and mature crop) or characterized their growth and performance (growth rate, resist drought, test weight, and seed germination). In the interviews, a majority of farmers were quick to suggest that a crops' overall appearance would indicate a soil's health. Crop yield, a measure of soil productivity, ranked tenth, yet its relationship to soil quality remained problematic. As one farmer put it:

> *Take a poor soil and a good manager. If [the manager] puts enough fertilizer in the row, and kills the weeds, he can still get an average to above average crop, and the soil could still be out of whack.*

A minority of farmers (39 percent) volunteered in open-ended questioning that the level of crop productivity was indicative of a soil's health. In follow-up questions that asked about the relationship directly, an additional 54 percent of the farmers (for a total of 93 percent) considered crop yield influenced by soil quality. A simi-

[1] Characterization of soil health properties was supplemented by interviews in a related field investigation in Walworth county, where six of these farmers were revisited in addition to two organic dairy producers.

[2] Romig, D.E., and R.F. Harris. In preparation. Survey, synthesis, and use of farmer knowledge in assessment of soil quality and health.

lar answering pattern was observed for yield-related categories that dealt with grain appearance and quality, specifically test weight and mature crop (Figure 1). It is interesting that, unless prompted, farmers chose indicators other than yield to determine the health of their soil.

Beyond soil and plant systems, the relationship of soil quality to animal health and water quality becomes more tenuous and difficult to document. With exception of chemicals in groundwater, properties of these systems ranked low in the interview analysis (Figure 1). But farmers did not dismiss animal health or water quality as important indicators of soil health:

> *A healthy plant is a healthy cow is a healthy milk check. It's all related to me.*

It remains to be seen if farmers representing different farming systems from different geographical locations will use similar soil and non-soil indicators of soil health functions (the ability of a soil to support biological productivity, promote animal and human health, and protect environmental quality). Additionally, it will be interesting to track future changes in farmer and scientist perceptions concerning soil quality and health properties and functions as new knowledge continues to be developed and exchanged.

Characterization of soil health properties. Farmers provided a wide variety of terms to describe properties of soil, plants, animal/human, and water that they consider reflective of soil health. Given this broad range of descriptive terms, subtle gradations of properties could be used by farmers to characterize soil health between healthy and unhealthy extremes. If soil quality exists on a continuum, what level of resolution is necessary for its evaluation? For many farmer assessments, Wilshusen and Stone suggest that three categories of soil quality (good, mediocre, and poor) may be sufficient; similarly, we use three categories (healthy, impaired, and unhealthy) in the *Wisconsin Soil Health Scorecard* (Romig et al, 1994; 1995). However, in practice, farmers in our interviews recognized soil health on essentially a dichotomous scale—healthy or unhealthy.

The multiple descriptive terms used by farmers to characterize soil health presents, in principle, a logistical problem for the condensation and use of this information. However, it is often possible to discern a common theme or pattern for a given soil health property. For example, a total of 30 different descriptions were collected for tillage ease, but most could be captured in the generalization that, for healthy soils, tillage was easier because the soil broke down quicker with less traction; unhealthy soils, on the other hand, were harder to work, requiring more horsepower and time to make a suitable seedbed. This approach was employed to develop a catalogue of healthy and unhealthy descriptive terms used by farmers for the top 20 soil health properties (Table 1).

The following is a distillation of the views of farmers on descriptive differences between healthy and unhealthy soils, recognizing that all farmers did not subscribe to all viewpoints expressed. Healthy soils were described by farmers as loose, soft, crumbly, flexible, mellow, darkly colored, and loamy. These soils were also characterized as having an abundance of earthworms; a sweet, earthy smell; and no problems with crusting or compaction. Unhealthy soils were described as massive, lumpy, or powdery; having a greasy or rough feel; being dense or solid; lightly colored; and too light or too heavy in texture. These soils were further described as having a sour or chemical smell, a surface crust, and a hard plowpan. Plants grown in a healthy soil were expected to have a large spreading root system with numerous feeder roots; thick, tall stems; and large, dark green leaves. Further, they would germinate better, grow at a vigorous rate, take longer to mature, and have grain with body and a higher feed value than those plants growing on an unhealthy soil. Overall, plants on a healthy soil would appear in a dense, uniform stand, show little or no signs of nutrient deficiencies, withstand drought and pest infestations, and be more economical to produce. Animals grown on feed from healthy soils were said to have less disease, and higher production. Wildlife was seen more often around farms with healthy soils, especially birds feeding on earthworms behind the plow. Half of the participants felt that human health was affected to some degree by their soil quality. Healthy soils were said to protect groundwater from chemical contamination and surface water from siltation.

Not all soil health properties are assessed by direct observation. Farmers appear to have an intuitive understanding of many local physical, chemical, and biological soil processes, and will determine the health of a soil from a multitude of observations under a multitude of conditions. This temporal perspective of soil quality is difficult for scientists to acquire. The partitioning of water at the soil surface, for example, can often suggest the soil's ability to absorb water. But water observed ponding or running off the soil surface does not immediately inform a person of the subsoil's ability to drain or hold water. It is by observing how their soils and crops respond to climatic extremes—times of intense precipitation, drought, and supersaturation—that farmers are able to deduce such properties as drainage, water retention, and aeration.

Farmer understanding of soil biological processes of healthy soils are again derived from observing a few conspicuous and familiar signs.

> *If you have a lot of worms in a soil, you know you have a good soil.*
>
> *In an unhealthy soil, you start losing all your microbes that help breakdown organic matter.*

Decomposition rates of crop residues and manures, in addition to the presence of earth-

Table 1. Selected descriptive terms for top 20 soil health properties

Rank	Soil Health Property	Descriptions: Healthy	Descriptions: Unhealthy
1	organic matter	as high as possible, at soil's potential, manure, compost, >3%, 2%, 7-8%, putting more back.	rough, lack of organic matter, less, low.
2	crop appearance	green, healthy, uniform, lush, dense stand, tall, larger, sturdy, stout, proper color, darker, good crop.	yellow, stunted corn, small, poor color, poorer, lack ofgreen, light green, streaks in field.
3	erosion	wouldn't erode, water & wind not taking soil, prevented, stays in place, less, slowed down, delayed.	blows sooner, washes, topsoil's lost, erodes more, clouds of dust, ravines, runs bad, any, easier.
4	earthworms	fishing & red worms present, see after rain, a lot, angle worms, see holes & castings, see during plowing.	not there, don't work, can't find, no holes, lack of, killed by insecticides or anhydrous, void.
5	drainage	water goes away, fast, better, no ponding, moves through, takes alot of rain, drains properly, dries out.	tight, waterlogged, drains too fast, ponding, no outlet for water, won't drain, slop, poor, saturated.
6	tillage ease	one pass & ready, breaks up, mellow, easier, smooth, crumbles, flows, plow a gear faster, minimum.	never works down, needs more disking, lumps, slabs, shiney, pulls hard, worked wet, overworked.
7	soil structure	won't roll out of hand, crumbly, loose, holds together, granular.	hard, doesn't hold together, lumpy, falls apart, massive, cloddy, lumpy, clumpy, tight, compacted, powder.
8	pH	7.0, 6.7-6.8, 6.2-6.7, balanced, neutralize.	<6.0, high, nothing works, wrong, too low, high acidity.
9	soil test	up to recommendations, high, elevated, complete, where it belongs, every year or two, stay up with soil test.	law of minimum at work.
10	yield	150-180 bu corn, 60 bu beans, 30-40% higher, +10 bu/ acre, better 5 year average, significantly higher.	110 bu corn, 150 bu corn, 35 bu beans, 20-50 % less, don't get much off, down, reduced, low.
11	compaction	doesn't pack down, not compacted, stays loose, not out there when wet.	compacted, plow layer, packs down, hardpan, plowsoil, tight, can't get into it, packed.
12	infiltration	water doesn't stand, absorbs, water moves into soil, soaks, rapid, no ponding, fast, spongy.	water runs off soil, sits on top, water stands, doesn't absorb, puddles, nonporous.
13	soil color	dark, black, dark brown, gray, holds dark color.	orange, brown, light, white, red, blue-gray, subsoil color, bleached, sandy colored, light brown, pale, anemic, gray.
14	nitrogen	put on less, manure, as required, compost, slurry, more available, organic N, organic matter.	Too much N, chemical N, commercial fertilizers burn ground, anhydrous, sludge.
15	water retention	holds moisture, get by with less, retains more, moisture travels, gives and takes water freely, conserving.	too much water, doesn't hold water, drys out, too wet or dry, droughty, stays wet, runs out of moisture, poor.
16	phosphorus	as required.	—
17	nutrient deficiency	has what it needs, no shortage of elements, no spots on leaves.	yellow, purple, discoloration in leaves, lodging, crop falls off, stripping, brown streaks, firings on bottom, blight.
18	decomposition	breaks down, decays, rots in 4-5 months, manure part of soil in 1 yr, disappears, not too fast, 2/3 gone in year.	see stalks from last year, doesn't break down, manure plows up next year.
19	potassium	as required.	—
20	roots	larger, spread out, grow down, white, deep, numerous, good penetration, full, lots of feeders, branched out.	don't penetrate, undeveloped, balled up, grow crossways, discolored, diseased, at hard angles, shallow, short.

worms, are measures farmers make over months, even years, which inform them about the condition of their soils.

This study showed that farmers rely almost exclusively on sensory observations to judge a soil's health. Even indicators considered essentially quantitative tended to be described qualitatively. For example, Table 1 reveals the absence of numerical references to soil tests and their constituent nutrient analyses (nitrogen, phosphorus, and potassium). Farmers were quick to enlist the help of a soil test when asked how they might determine the quality of an unfamiliar field. But when prompted, farmers were uncertain as to exact nutrient levels they would consider a healthy soil to have. Rather:

> *We like to see everything up to, and a little above, the recommendations.*

Furthermore, the response "as required" farmers gave for nitrogen, phosphorus, and potassium (Table 1) would seem to indicate that soil fertility is human-made, a technical attribute rather than an inherent soil property (Williams and Ortiz-Solorio). And while soil tests are tools that help distinguish healthy from unhealthy soils, they may serve a more important role in advising farmers of the amount of corrective action required to build or maintain soil fertility.

> *If a farmer wants to improve his system, he has to start by testing the soil yearly.*

Numerical descriptions were emphasized, to varying degrees, for only five properties (organic matter, pH, yield, grain test weight, and topsoil depth). By and large these values defined a range farmers knew they could work within rather than a precise value. For example, 15 of 20 descriptions for soil pH were numerical, defining a range for healthy soil between 6.2 and 7.0. Quantitative values were given less often for soil organic matter; eight of 26 farmer descriptions targeted the range of 2 to 8 percent organic matter for soils of high quality, recognizing its variability with respect to soil type. The remaining descriptions for organic matter reveal that farmers prefer to be "at the soil's potential" and detailed methods to improve organic matter levels:

It takes a long time to create a healthy soil; plowing under trash and manure and trying to build humus.

Though farmers held a common ideal for most soil health attributes, consensus among them was not found for all properties. As indicated in Figure 1, conflicting descriptions were given for weeds, soil type, landform/slope, and the ratio of calcium to magnesium of healthy and unhealthy soils. While most farmers believed a healthy soil would grow more weeds, others thought weeds were a sign of poor soil health, indicative of nutrient imbalances. Soil type seemed to be a function of personal preference, though many farmers showed an affinity for loamy soils developed under prairie vegetation. Nevertheless, farmers did not exclude other soil types:

If you are getting into a heavy clay, you are going to have to understand it....to tie it into your program.

Two farmers described their ideal soil as having a dark loam above a clay subsoil, with something underneath to improve drainage. In general, most farmers were reluctant to compare different soil types:

There's prairie soil, tight clay, gumbo, and peat ground....It's tough to compare [their quality]. You really shouldn't do that. You should look at one soil type.

Landforms and slopes were again a matter of preference and had more impact on management than on the health or quality of the soil.

Level land isn't necessarily the best land. Gently rolling is the best, because then water at least has a place to run.

You may have a good soil, but if it's on a real good slope, you'll need to be more careful on it.

Finally, calcium and magnesium were frequently mentioned as important nutrients, but a specific ratio between them was not addressed by these farmers.

Soil health as practice. Appraisal of soil health by farmers was not limited to soil, plant, animal, or water properties. Farmers repeatedly referred to management practices as indicators of soil quality. The following pattern emerged in the analysis of the interviews: healthy soil is not only a state that is recognizable, it is also a phenomena in which farmers actively participate. An insightful dairy farmer put it in this way:

As soon as you set the plow in the ground, you are working against nature....Then you have to start managing and start thinking ahead.

In one case, when asked how an alternative strategy of frost-seeding alfalfa related to soil health, a dairy farmer responded:

This is soil health! It is all part of it! I'm not out there working the ground, trying to get [the soil] prepared for alfalfa. I'm changing the thinking pattern.

In the minds of farmers it appears that the management and the measurement of soil health are inseparable parts of a dynamic system (Alcorn).

Farmers engage in activities that directly impact the health of the soil. For the years that follow, farmers measure the impacts of those management decisions. They are also aware of practices carried out on neighboring fields, often making fenceline comparisons:

The neighbor has had corn for 15 years straight....You can see the difference in color. Right across the fence, our soil looks a little darker, richer.

Farmers spoke to several management practices that are part of their diagnosis of soil health:

- **Chemical use**

  I think some soils that have been cropped year after year, with heavy amounts of pesticides, chemical fertilizers, and anhydrous, are dying.

- **Rotations**

  If I see something that is in continuous corn, I know that soil is not healthy. I'd like to see the rotation.

- **Tillage practices**

  I believe a lot of soils are ruined because they are worked at the wrong time, often when they're too wet.

- **Fertility management**

  My soils [have been] built up pretty good by hauling manure and putting on some commercial fertilizer and lime.

- **Conservation techniques**

  Soil erosion is often dictated more by farming practices and management, and less by issues of healthy soil.

Comments such as these suggest that farmers focus as much or more on processes they believe create or destroy soil health than on the properties themselves.

Farmers possess a series of management activities or "scripts" related to soil health. Scripts embody cultural ideals and take care of many details that would otherwise divert a farmer's attention from farming (Alcorn). Complex biogeochemical processes associated with crop rotations, for example, are beyond the everyday concerns of a farmer, but such a script does reveal a tacit understanding of the soil resource and the requirements for sustained production.

To me, there is something about having hay in a rotation that makes a soil more healthy. Now, there is some soil that will never see hay. It's still a healthier soil to me if it has a rotation of corn and soybeans verses just straight corn. And if I can rotate

Figure 2: **First page of soil section in the *Wisconsin Soil Health Scorecard***

SOIL– Questions refer primarily to the plow layer

Descriptive Properties	SCORE
1. EARTHWORMS	
0 Little sign of worm activity 2 Few worm holes or castings 4 Worm holes and castings numerous	
2. EROSION	
0 Severe erosion, considerable topsoil moved, gullies formed 2 Moderate erosion, signs of sheet and rill erosion, some topsoil blows 4 Little erosion evident, topsoil resists erosion by water or wind	
3. TILLAGE EASE	
0 Plow scours hard, soil never works down 2 Soil grabs plow, difficult to work, needs extra passes 4 Plow field in higher gear, soil flows & falls apart, mellow	
4. SOIL STRUCTURE	
0 Soil is cloddy with big chunks, or dusty and powdery 2 Soil is lumpy or will not hold together 4 Soil is crumbly, granular	
5. COLOR (MOIST)	
0 Soil color is tan, light yellow, orange, or light gray 2 Soil color is brown, gray, or reddish 4 Soil color is black, dark brown, or dark gray	
6. COMPACTION	
0 Soil is tight, compacted, cannot get into it, thick hardpan 2 Soil packs down, thin hardpan or plow layer 4 Soil stays loose, does not pack, no hardpan	
7. INFILTRATION	
0 Water does not soak in, sits on top or runs off 2 Water soaks in slowly, some runoff or puddling after a heavy rain 4 Water soaks right in, soil is spongy, no ponding	

with a year of wheat, I think it's even healthier for the soil. I don't know why [soil] needs small grains or hay, but I feel it should be in the rotation.

Following scripts, farmers use natural processes to their advantage and guarantee that the final product is of high quality.

While current scientific investigations seek to establish analytical protocol to assess management effects on soil quality, many of the farmers in this study have already judged certain management practices as either beneficial or detrimental. Farmers recommended several practices to maintain and improve soil health—the addition of manures and compost; cover cropping; rotations with hay, sweet clover, oats, or wheat; liming; keeping micronutrients in balance; maintaining waterways; and practicing conservation tillage. Practices some farmers thought to avoid included plowing when wet, producing cash grain crops continuously, and applying anhydrous ammonia.

Farmer knowledge in soil quality research

Within recent history, soil quality was considered by most scientists and farmers largely, if not solely, in terms of soil chemical properties defining the soil's capacity for crop production. Farmer knowledge of soil fertillity was not necessarily disdained by scientists, but was disregarded because of the exclusively analytical nature of soil fertility management.

Driven largely by groups external to agricultural science and the farming establishment, the sustainable agriculture movement relied heavily on the knowledge of farmers using alternative methods to build its case while questioning conventional production practices. After a period of mutual suspicion, distrust, and even contempt by production agriculturists and environmentalists, diverse scientists and farmers are now converging conceptually on a similar broad definition of soil quality and health. For example, a soil quality task force established by the Soil Science Society of America currently defines soil quality as "the capacity of a specific kind of soil to function, within natural or managed ecosystems, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al. 1995).

This expansion in the scope of soil quality challenges scientists to develop soil quality assessment tools and strategies that not only serve well in research, but meet the generalized needs of all landowners and local communities (Acton and Padbury). Further, while soil quality indicators fit into familiar chemical, physical, and biological quantitative analyses, they must be converted to relative value-based indices, which address different soil quality functions, perhaps using a systems engineering approach (Karlen et al. 1994; Karlen and Stott). This conversion process involves subjective decisions that implicitly confer a qualitative nature to soil quality indices (Granatstein and Bezdicek). Perhaps this is an even greater challenge to soil quality research, acclimating the scientific community to soil health and quality indices that qualitatively integrate analytical and/or descriptive data.

One outgrowth of our interview study has been the development of the *Wisconsin Soil Health Scorecard* (Figure 2), a farmer-based field tool to assess and monitor soil quality and health (Romig et al. 1994, 1995). The scorecard reflects the priorities, language, and intent of the growers we interviewed, and allows for holistic evaluation of soil, plant, animal, and water properties. Figure 2 illustrates how the index assesses soil health properties through a series of question patterned after indices used in human health and behavioral sciences (Bowling; Streiner and Norman). Each question measures a soil health property along a 0 to 4 point scale, directly incorporating a value judgment for unhealthy (0), impaired (2), and healthy (4) options. Final scores are totaled for each system and, depending on the needs of the user, system scores can be compared to one another or compiled into a total soil health score for a particular site. The scorecard provides a farmer-based assessment of soil health that has, in addition to inherent value, potential for use as a reference base for soil quality assessment, and a soil health data source for an integrated soil quality and health scorecard.

Descriptive and holistic approaches used by farmers to characterize soil health have practical implications for soil quality work by scientists. First, descriptive indicators of soil health provide a mechanism for field assessment and monitoring of soil quality by scientists and farmers. Possible connections between farmer and scientist descriptive indicators of soil quality are given by Arshad and Coen, and Reganold et al., including surface crusting, evidence of erosion, ponding of water, vegetative cover, soil structure, friability, and consistence. These indicators integrate well with the properties identified in this study and provide a base for bridge-building between scientists and farmers to develop mutually acceptable descriptive indicators for soil health and quality.

Second, the holistic manner in which farmers interweave properties of the soil per se with properties of plant, animal/human, water, and air systems they consider an integral part of soil health, has conceptual value for scientists, particularly in the development and validation of indices addressing the functions of soil quality. To date, however, recognizing non-soil properties such as vegetative cover in characterizing soil quality is the exception rather than the rule.

Third, the high priority that farmers place on certain descriptive soil health indicator properties supports their inclusion of corresponding analytical properties as soil quality indicators. There is also scientific incentive to critically examine the basis of underlying farmer priorities and assumptions. For example, the importance attached by farmers to soil organic matter, soil organisms, and biological processes gives direction and support for including biotic properties as legitimate analytical components of soil quality. It also underscores the need for scientific evaluation of the relationship between biotic properties and soil quality. Similarly, farmer perceptions about the relationship of weeds to soil quality would appear worthy of scientific examination.

Fourth, farmers perceive the relationship of soil health to cropping systems and other management practices as dynamic rather than linear, measured not only by discrete properties but by the activities themselves. Furthermore, farmer understanding of management effects on soil health appear to warrant scientific investigation to interpret and predict the consequences of management on soil quality.

Finally, the broadening definition of soil quality provides a bridge-building opportunity for productive interactions and mutual understanding between scientists and farmers. We must continue to face the challenge of combining the best of scientific and farmer perspectives and knowledge to meet the demands of regenerating soil quality and health. Sustainability will come through the rediscovery and acknowledgment of the unique perceptions and adaptations of farmers in partnership with new research (Orr; Harris et al.). With greater understanding of soil stewardship through farmer/scientist partnerships, it will be possible to design better policies and implement appropriate programs to monitor, assess, and build healthy soil.

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