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PERSPECTIVE

Soil health—useful terminology for communication or meaningless concept? Or both?

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What is soil health? It is not essential to have a degree in soil science in order to have a valid opinion on this. In a very general sense, almost everybody has some impression of what is meant by a healthy soil, especially anyone who has done any gardening or even looked after a potted plant on a windowsill. They will probably say it should have a beautiful crumbly structure, should hold water but not become waterlogged, and be teeming with life; provided that life does not include insects or pathogens that damage the plants. In a somewhat analogous way, the word "wellbeing" is used concerning the way individual humans feel about themselves and we will all have our own ideas on what contributes to our personal wellbeing. It is likely to include being in good physical and mental health, being adequately fed and being housed. However, social scientists have taken the idea further, developing indicators of wellbeing and even using these to compare the state of wellbeing in different countries and assess the impact of policies on the way people feel. Some may consider that this is taking the "wellbeing" concept too far. With soil health, perhaps soil scientists make it too complicated. However, although anyone may have a general idea of what makes a healthy soil, if the term is to be used in anything other than general informal conversation, we do need to "dig a little deeper", if readers will excuse the pun.

1 Some history

Since time immemorial humans must have developed some concept regarding the functioning of soils. Bünemann et al.[1] cite ancient Chinese texts dating back to 2070 BCE referring to the assessment of the suitability of soils for crop growth. And presumably even our hunter-gatherer ancestors would have noted that soils in specific locations were more successful than others in producing plants that were useful for food, fiber, fuel or construction materials, or for providing food for animals that could be hunted. As humans became settled, villages and later cities usually developed in areas where the surrounding land was capable of producing sufficient food for the population. This is one reason why the massive expansion of cities over recent decades has had a negative impact on global food security, as some of the most productive land is lost. Hillel[2] argues that the decline of several ancient civilizations can be attributed to their failure to maintain the soil properties and functions essential for their food production. For example, chapter titles in the book *Out of the Earth* include "Silt and salt in Mesopotamia", "The promise and peril of irrigation" and "Accelerated erosion".

When I began my career in soil science in the 1960s, the term "soil fertility" was commonly used as a way of describing the success (or failure) of specific soils to grow agricultural crops. This term clearly has its limitations because it is usually limited to agricultural uses of soil. The wider ecosystem functions of soils, or the importance of non-agricultural land such as forests or savannah within global ecosystems, were not well recognized at that time. And even within an agricultural context the term tended to be regarded as only describing the availability of nutrients to crops, perhaps overlooking other soil properties. However, other constraints were well recognized at the time,

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including poor physical structure, salinity, stoniness, shallow soil depth and excessive slope. Land capability schemes were devised to classify the suitability of soils for agricultural use, based on the extent of such constraints; these were interpretations of traditional soil maps. One example is the Land Use Capability Classification for the UK published over 50 years ago[3] which was, in part, inspired by an earlier system developed for the USA[4].

2 Enter soil quality

A 1977 conference paper by Warkentin and Fletcher[5] is usually cited as the first scientific publication to use the term "soil quality" but Bünemann et al.[1] cite an earlier paper by Mausel[6] published in 1971 describing the suitability of different soils in Illinois, USA, to grow various crops. Through the 1980s and 1990s the term became increasingly prominent and widely used (Fig. 1) and a conceptual framework developed. This took place in parallel with an increasing awareness by land managers, policymakers and others of the importance of soil in delivering many of the unseen environmental goods and services on which society depends. For example, Constanza et al.[7] attempted to estimate a monetary value of total global ecosystem services and arrived at a figure of 33.3 trillion USD per year; it can be argued that 80% of this value is linked to soil functions, and consequently human welfare can be directly linked to the efficient and effective functioning of soil[8]. So "soil quality" was a significant development from "soil fertility" (if used in its narrowest sense of only referring to nutrients), being a more holistic description and assessment of soil functions. The term "soil quality" and the associated concepts are wider than agriculture, though they include agriculture as this is one of the "provisioning services" within the ecosystem services paradigm[9], the other services being supporting, regulating and cultural. A further perceived value in the term "soil quality" (often abbreviated to SQ) was understandability by non-specialists. It was thought that most people, including politicians and policymakers, could relate to the concept more easily than to a more technical description of specific soil properties or functions, especially as "quality" was increasing used for describing the properties of water and air.

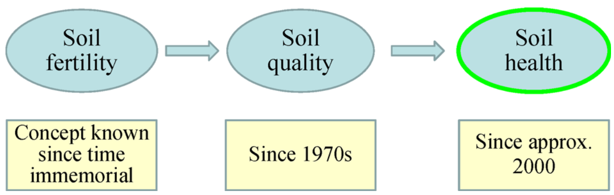

Fig. 1 Development of terminology for assessing soils and their ability to function.

A particularly influential action in promoting the term and concepts of SQ was the establishment in 1994 of a committee by the Soil Science Society of America to "define the concepts of soil quality, examine its rationale and justification, and identify soil and plant attributes that would be useful for describing and evaluating soil quality"[10]. Interestingly this committee was established in response to questions on the subject by policymakers and others following publication of a book entitled *Soil and Water Quality: An Agenda for Agriculture* by the US National Academy of Sciences[11]. Perhaps this was an example of soil scientists at that time being unable to respond to the requirements of policymakers and having to rapidly learn how to communicate more effectively with fellow citizens who were not soil science specialists but did have a vital interest in the properties and functioning of soils.

3 Can soil quality be quantified?

The general idea of SQ became widely accepted but arguments raged among soil scientists as to whether it could be quantified in a meaningful way. A paper by Karlen et al.[10] that promoted the idea of quantifying SQ was followed by a strong critique of the whole SQ concept by Sojka and Upchurch[12]; both groups then expanded on their arguments in major reviews[13,14]. A major point of disagreement was whether SQ could be quantified in the sense of stating an index as a numerical value. Some soils scientists argued that this was a helpful way of summarizing a mass of data but others said that, for making management decisions, it is individual soil properties that matter. If a soil is classified as of low SQ, the land manager needs to know the specific cause if it is to be corrected. For example, whether it is because of acidity, so the soil needs liming, or because of low nutrient levels to be corrected by applications of fertilizer or manure.

Stockdale and Powlson[15] considered that the term “soil quality” was useful in general discussion with policy makers and members of the public and it was necessary for soil scientists to use it. However, they also considered that attempts to quantify SQ as a single value by combining measurements of a range of soil properties can quickly move toward unimaginable complexity and so become counterproductive. They also pointed out that there was a fundamental difference in applying the word “quality” to soil as compared to water or air. With water and air “quality” normally refers to the presence or absence of unwanted pollutants such as nitrate, pesticides or phosphate in water or nitrogen oxides, ammonia or particulates in air. Concentrations of such substances are compared with values considered safe and, at least in principle, there is a possibility of having pure water or air containing no contaminants. With soil it is different for several reasons. While defining acceptable concentrations of contaminants is certainly one aspect of considering the “quality” of a soil, every soil has some background content of elements or compounds that, if present at too large concentrations, would be undesirable. For example, compared to other soil types, serpentine soils naturally contain high concentrations of nickel, chromium and cobalt derived from the parent rocks – not from pollution. In contrast to water or air, there is no such thing as a “pure soil”: all soils have a legacy of elements or compounds naturally derived from their parent materials and this natural background varies from place to place. Another difference is that soils have positive characteristics, such as organic matter content, aggregate stability and biodiversity; these contribute in a positive way to their “quality” in addition to the negative impact of contaminants.

In some respects, soil quality is more parallel to food quality rather than water or air[15]. Food quality is defined by a combination of (a) limits for undesirable contaminants and (b) the quantities of substances considerable desirable for human nutrition such as protein, vitamins or antioxidants. A further complexity regarding soil quality is that different soil attributes are required depending on the use to which the soil is put. For example, a soil used for growing horticultural crops will generally need a high concentration of nutrients and a neutral or alkaline pH. By contrast, a soil to be used for growing coniferous trees will require a low nutrient level and acidic pH. Also, as a foundation for buildings, very different physical properties are required based on soil mechanical strength. Most soil scientists will agree that, in a scientific sense, the term “soil quality” in isolation is meaningless; it only has meaning if linked to a function. Quality for a specified use, e.g., lettuce growing, forestry, natural vegetation, water catchment, flood defense. It is notable that this point was made in the earliest publication using the term “soil quality” as applied to Illinois State, USA[6]. The author states: “There is no one true soil quality map of Illinois. Soil quality depends on the criteria by which it is defined. This study defines soil quality as the ability of soils to yield corn, soybeans and wheat under conditions of high-level management.”

4 Multifunctional soils

The concept of multifunctional landscapes is now well established[16,17]. The principle is that many landscapes need to simultaneously provide food security, livelihood opportunities, maintenance of species and ecological functions, and fulfill cultural, aesthetic recreational needs. To meet these challenging requirements, the soils present in the landscape need to effectively deliver several functions simultaneously. Although many soils in specific locations continue to have a *primary* function (e.g., agriculture), they almost inevitably perform others such as water catchment, contributing to flood defense, or as a source or sink for greenhouse gases. So when considering the “quality” of a soil there are frequently trade-offs between the way it will perform the different functions. An obvious example is a soil used for agricultural production, requiring a high level of nutrients and organic matter, but the same soils also contributes to water catchment such that high levels of N or P are undesirable. Such trade-offs can be addressed through management practices such as regulations regarding the quantity and timing of fertilizer and manure inputs within the Nitrate Vulnerable Zones in the European Union. However, to capture these issues within a soil quality framework seems virtually impossible.

5 Soil health

The idea of a healthy soil arose, at least in part, from the organic or biological farming movement in Europe in the early twentieth century and predated the use of the term “soil quality” by many decades. However, the widespread use of the term “soil health” is more recent; probably over the past 20 years and it has tended to supersede the use of “soil quality”. Some soil scientists argue that the concept of “soil health” is more holistic than “soil quality” and better encompasses biological aspects. Others argue that this distinction is false, and the two terms are synonymous; indeed, some schemes of soil quality assessment explicitly include biological aspects, so whether or not the terms are distinct can be simply a matter of definition. The relationship between soil quality and soil health, and whether or not they are different, is discussed in detail by Bünermann et al.[1]. I suggest that the terms are effectively synonymous, and the same reservations discussed above regarding attempts to quantify “soil quality”, as opposed to measurements of specific soil properties or functions, apply equally to “soil health”. So, in a scientific sense, I do not consider “soil health” to be useful concept or term. However, it does have value as a communication tool. The word “health” appears to resonate more strongly than “quality” among non-specialists including policymakers and thus can be valuable, whether or not it has a specific scientific meaning or is readily quantifiable. There is also, perhaps, the unspoken idea that soil can have health attributes that parallel human health and thus indicate a personal link with the soil. The UK government’s 25 Year Environment Plan[18] refers specifically to soil health. It includes sections headed “Improving soil health and restoring and protecting our peatlands” and “Developing better information on soil health”. Also, there is a specific commitment to develop a soil health index.

The concept of “soil health” also appears to have resonance within some sections of the farming community in the context of sharing information on innovative management practices. For example, the American Farmland Trust publishes case studies demonstrating how promoting soil health has improved the profitability of specific farms. It is informative to read the range of management practices that are described as contributing to “soil health”. In the case of a farm growing almonds in California they include closer management of nutrients through leaf analysis and fertigation, application of composts and growing native vegetation as cover crops during winter. Another example was introduction of cover crops and zero tillage in a maize-soybean rotation in Illinois. It could be argued that these are simply positive improvements to the management of these systems and the use of the term “soil health” is unnecessary: in fact, returning to the much older terminology, these practices might be described as improving “soil fertility”. However, if “soil health” is an effective umbrella term for the communication and promotion of such beneficial practices, it deserves to be welcomed.

In another example, in 2014 the Government of India introduced Soil Health Management as a component of the National Mission for Sustainable Agriculture. As part of this, farmers have been issued with soil health cards and laboratory analyses are conducted with funding from national or regional governments. The analyses are pH, electrical conductivity, organic carbon and a range of plant available nutrients. Fifty years ago this set of analyses would have been described as a “soil fertility” assessment but clearly a decision was taken that using the term “soil health” was beneficial for the purposes of communication with farmers. Similarly, in the UK the agricultural consultancy group ADAS uses the term “soil health” to describe its soil management activities in communications with farmers.

For many years the Cornell Soil Health Testing Laboratory has offered a soil health assessment service based on research at Cornell University, USA. The standard test comprises analysis of soil texture, pH, organic matter plus a fraction termed “active carbon”, several nutrients, soil respiration, a measure of protein content and several physical attributes. Again, it seems that the term “soil health” is being used as a communication tool that is considered helpful by some users of the service, but what is actually delivered is a set of soil physical, chemical and biological measurements which each have a value in assessing the state and functioning of a soil. It does not seem that “soil health” as an overall and specific concept is being promoted. Similarly, ten Berge et al.[19] emphasize the importance of measuring and considering specific soil properties in the context of the purpose for which a given soil is being used and to consider specific soil or environmental threats. Although the title of their paper, “*Soil quality: a confusing beacon for sustainability*”, refers to soil quality rather than soil health, it could equally well apply.

6 Concluding comments

If the term “soil health” is an effective communications tool for conversations with fellow citizens, land managers, politicians and policymakers then soil scientists should certainly use it. Ensuring that soils function in the ways required for humans in the long-term is a vital matter, on a level with combatting climate change. However, compared to the global-scale threat of climate change, changes in the properties of soil may superficially appear to be dull! Any device for communication that makes it easier to convince non-specialists and influencers of the importance of maintaining soils in a good condition so that they can effectively meet the functions required by society should be enthusiastically grasped and used to the full. But I suggest that soil scientists should be wary of over-complicating the subject and risk turning soil health (or quality) into an art form in which we become overly focused on terminology. At a technical level, and in the context of providing land managers with information as a basis for management decisions, we fully understand that it is measurements of specific soil properties that matter. However, in policy-level discussions, or initial conversations with non-specialists, if using the term “soil health” is helpful, we should use it.

Fortunately, technological developments are making it easier to conduct routine monitoring of soils in less expensive and labor-intensive ways. These include a variety of sensors for both crops and soils which can be mounted on drones or tractors, or used as hand-held devices associated with mobile phones, and methods based on reflectance spectroscopy[20,21]. One aspect of soil monitoring of agricultural land is to provide farmers with improved information as a basis for decision making, both in-season management and long-term decisions on practices or cropping systems which can have far-reaching implications for the wider environment. Another aspect is monitoring soils at the national or subnational or regional scale; there are at least two reasons for undertaking such monitoring. First, to detect trends which may not be easily apparent within the scale of individual farms but have implications for the sustainability of agricultural systems and hence strategic implications for governments regarding food security. Second, to assess the wider environmental implications of large-scale changes in land use or management, for example implications for regional hydrology, water resources or biodiversity.

Two quotations are relevant to soil health and the ways it is influenced by human activities. One made by a former US President more than 80 years ago: "The nation that destroys its soil destroys itself". The other, pointedly relevant to the health and functioning of agricultural soils: "Sustainable agriculture is not a luxury …. When an agricultural resource base erodes past a certain point, the civilisation it has supported collapses …. There is no such thing as a post-agricultural society."[22]

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