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COMMENTARY

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# Soil health at a crossroad

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Lehmann et al. (2020) recently published an article in which they propose a review of the very topical notion of soil health and of its practical significance for soil management. Unfortunately, the journal in which this review appeared does not accept comments or letters to the editor, thereby depriving the scientific community of the opportunity to debate in a timely manner some of the startling conclusions the authors reached, which arguably run the risk of encouraging researchers to venture down a very slippery slope. A commentary on Lehmann et al. (2020) is offered here, in the hope that it will lead to a constructive discussion about some of the limitations of the concept of soil health, and about how to proceed to come up with an alternative approach that would be more directly useful in terms of soil management.

Over the past 3 decades, efforts to address critical soil issues and make decision-makers aware of their societal importance have very often involved the concept of 'soil quality', and in the last decade, increasingly that of 'soil health'. This latter term arguably draws much of its appeal from a close connection between soils and animal or human health (e.g., Oliver & Gregory, 2015), which various authors, like Howard (1945) and Voisin (1959), identified a long time ago. While the use of these terms has become steadily more common outside the scientific community, soil scientists have consistently struggled in practice with their definition and quantitative assessment. Long lists of physical-, chemical- and less frequently biological 'indicators' allegedly associated with the quality or health of soils have been proposed by various researchers. So far, no consensus of any kind has been reached on how many indicators are pertinent, and their number seems likely to grow in the near future. Indeed, Lehmann et al. (2020) recommend that several other biological parameters (related to biodiversity at different scales) beside those considered thus far should also be taken into account. Different ways of combining existing lists of indicators into distinct 'soil health indexes' have been devised, and when these indexes have been confronted with actual data, results have tended to be underwhelming (e.g., Roper et al., 2017; Caudle et al., 2020). The state-of-the-art in this field is aptly captured by Lehmann et al. (2020), who point out that researchers have so far not yet resolved the 'challenges of defining soil health in a way that allows for a universal quantitative assessment'.

Long ago, William Thomson (Lord Kelvin) opined that 'when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be' (Thomson, 1889). From this perspective, the protracted lack of definition and hence of quantitative assessment of soil health must be considered a serious problem. This point was made particularly clearly by Bouma (2021) in a recent comment: 'if we embrace the soil health concept we better make sure that we can measure it, like we now routinely measure the quality of water, air, nature and biodiversity. Thirty years or more of soil quality research (Bünneman et al., 2018) has not resulted in an operational measurement methodology. […] We simply cannot afford the same failure for soil health'.[1]

[1]Essentially, the same comment was made to me more than 20 years ago by my colleague, the late Armand Van Wambeke, who for a short time was a member of a 'soil quality' working group at Cornell, involving a single soil scientist (him) and a large number of agronomists, plant breeders, sociologists and economists. After a meeting where the group decided (unanimously, minus one vote) not to define the concept of 'soil quality' precisely, 'to keep the discussion open', Armand shared with me for hours his intimate, and it turned out premonitory, conviction, based on his long experience, that this decision was a clear recipe for failure. The working group stopped meeting less than a year later.

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This sentiment that it is crucial to define precisely the concept of soil health, and to come up with an operational measurement methodology for it, is apparently not shared universally. Indeed, as a somewhat stunning take-home message of their review, Lehmann et al. (2020) suggest that 'researchers should embrace soil health as an overarching principle to which to contribute knowledge, rather than as only a property to measure'. In other words, we are encouraged to forge ahead, and not let our crippling inability to define or measure soil health hold us back in any way. Unfortunately, in the absence of a consensus about operational means to measure soil health, it would seem difficult to keep any debate on soil health from degenerating into utter confusion, as scientists, environmentalists, and decision makers would have no common vision of precisely what they would be referring to when they would talk about it. It would be challenging under these conditions to 'contribute knowledge' to the debate in any meaningful way, or ensure that the concept of soil health has practical impact. The quagmire that soil health viewed as an elusively conceptualized 'overarching principle' is likely to lead to might reach particularly epic proportions if one were to follow Lehmann et al.'s (2020) additional suggestion that soil health, undefined though it is, should be recognized legally as a 'common good', a move that no doubt would attract hordes of attorneys into the fray! In the long run, the absence of a clear, quantifiable and agreed-upon definition of soil health will also make it very difficult for practitioners, in particular farmers, to know what to do practically to maintain it, which means that whatever we write about this topic is unlikely to lead to concrete, positive action.

Those who doubt that this forecast would materialize might be interested to know that there is a noteworthy historical precedent for this kind of 'overarching principle', which Lehmann et al. (2020) do not cite and few soil scientists seem aware of (see rare exception in Clothier et al., 2013), even though it is highly pertinent to the debate at hand. In a series of celebrated articles and books published in the 1940s, Aldo Leopold (1944, 1949) introduced the concept of 'land health' as a unifying goal for the 'house divided' that he felt environmental conservation had become. Land, for Leopold, included more than soils, but in many respects, the philosophy behind his 'land health', which he did not define operationally, was not very different than what Lehmann et al. (2020) advocate. Some researchers (e.g., Berkes et al., 2012) consider that, at an abstract level, Leopold's concept of land health has been influential and, in particular, has been a key inspiration for the 'ecohealth' movement. However, one could equally argue that because it was born in vagueness and never really evolved beyond it, Leopold's 'land health' has not helped bring about the change in environmental management that one could have hoped for initially. In a 2005 article in which they contended that 'land health' is preferable in practice than the ill-conceptualized notion of 'sustainability', Newton and Freyfogle (2005) nevertheless conceded that land health 'will not be easy to define, and […] very much needs definition'. It still lacks such definition today, many decades after Leopold coined the term.

If we want to avoid the confusion that would ensue in discussions about soil health in which everyone uses a different definition, based on different lists of indicators, and where there is no consensus on a measurement methodology, perhaps the best for the time being would be to stop focusing our attention on soil health, and to focus instead on what we are trying to achieve with it. In this respect, the first question we should ask is whether we really need concepts like quality or health, or similarly inspired alternatives, to advocate for soils or to manage them. To convince the public at large of the importance of soils, perhaps some simple slogan or vivid image with which public relation experts could come up might be far more effective than any of these concepts. Surely we can do better, in this day and age, than trying to convince the public of the key significance of soils with parameters nobody can really define precisely, let alone evaluate practically! Not to mention the risk of losing credibility when the public realizes that we do not have much of a clue of what we are talking about. In terms of soil management, soil scientists can, and routinely do, address issues like the degradation of soils, the impact of climate change on them, or their growing inability to fulfil essential ecosystem services, without ever invoking concepts like soil quality or soil health. That does not mean of course that there is no room for improvements in how we address these various issue, far from it! Especially in terms of ecosystem services provided by soils or to which soils contribute, we are just beginning to understand at a fundamental, quantitative level which aspects of soils are key to the delivery of specific services. That is in part because until recently, we had no way to measure most of these services directly, and therefore could not determine which soil parameters were relevant (Bagstad et al., 2018; Baveye, 2017; Lautenbach et al., 2019). For example, except with some services where it is obvious that soil biology plays no role (e.g., extraction of sand, clay, or water, or support of infrastructures), it is difficult to assess which type of biodiversity, species- or functional, at what spatial scale, may influence specific soil services, if we cannot assess these services quantitatively. Progress is slowly being achieved in this respect (e.g., Chalhoub et al., 2020), but the absence of a comprehensive model of soil behaviour or 'theory of soils', yet to be developed (Baveye et al., 2018; Neal et al., 2020), means that we still lack objective criteria to identify among the myriad of soil parameters those that, mechanistically, are indispensable indicators of the ability of soils to deliver specific services to human populations.

When, probably in a few years from now, we get to a stage where we become reasonably confident we have determined the complete list of soil parameters that control

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the ability of a soil to deliver the various service(s) that we expect from it (and not just the service associated with crop production), we shall be in a position then to assess whether there is a way to combine these parameters numerically into a single index, and whether it makes sense practically to do so. These questions are far from obvious. Indeed, it seems that any kind of parameter combination would rapidly prove useless, because of unavoidable and undesirable compensations among negatively- and positively scored parameters. In addition, from a practitioner standpoint, a single index value is likely to be of little utility. Indeed, if a soil is classified as having low soil health, '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' (Powlson, 2020).

Another practical argument against the idea of defining a numerical index that somehow would encapsulate all relevant soil characteristics is that it makes no sense to envisage such an index in the absolute. The situation we face with soils in this respect is similar to our perception of human health, be it physical or mental. Decades ago, the perception of the medical profession was that human health could be defined in the absolute, but progressively the thinking evolved and it was realized that health could not be apprehended without some reference to planned activities. As a result, since 1984, the World Health Organization defines health as 'the extent to which an individual or group is able to realize aspirations and satisfy needs' (WHO, 1984).

Mausel (1971) who, apparently, first coined the term 'soil quality' almost 50 years ago, realized that this index necessarily has to be tied to a specific use of the soil for which it is calculated. Many researchers since then (e.g., Baveye, 2020; Baveye et al., 2016; Bünemann et al., 2018; Letey et al., 2003; Schröder et al., 2020; Sojka & Upchurch, 1999; ten Berge et al., 2019; Wander et al., 2019) have similarly argued that only if one considers a specific function or service can one determine whether the characteristics of a soil are suitable or not. As Powlson (2020) points out, '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'. As another example, significant contamination of soils with copper (Cu), even well above regulatory standards, may not cause dramatic problems in vineyards (Jacobson et al., 2007) or if a key soil function is to support infrastructures (buildings, roads), whereas it could lead to potential health hazards for human populations if the use of the soil involves the production of root crops (Coelho et al., 2020). It is easy to come up with many more such illustrations of the fact that 'different soil attributes are required depending on the use to which the soil is put' (Powlson, 2020). This point needs to be stressed because it brings into question whether the health metaphor is in fact appropriate when dealing with soils, in spite of the emotionally satisfying connection it might emphasize between humans and their terrestrial environment. Indeed, one could argue that, unlike in general with humans, the ability of a soil to fulfil some functions may be in direct conflict with its ability to fulfil others. For example, improvement of the moisture retention capacity of a soil so that it is able to store more effectively the rainwater it receives, and to supply it to plants, may not be optimal in terms of a number of other functions, e.g., aquifer recharge.

In this general context, the situation we are in at the moment with respect to the concept of soil health is perhaps best described graphically by a very popular cartoon due to Wiley Miller (2016), which represents people choosing between two different directions at a crossroad. Under a big 'answers' sign, an arrow labelled 'simple but wrong' points to a path that many people follow, but leads straight to a precipice. Another sign, labelled 'complex but right', points to a path on which very few people venture, who appear to be intensively reading books as they proceed further. This path is long and sinuous, but eventually leads to the top of a hill. In terms of the concept of 'soil health', it would seem simpler not to worry about its precise definition and to refer to it as an 'overarching principle', as suggested by Lehmann et al. (2020). However, this path raises several difficult questions, to which at the moment there is no satisfactory answer. Historical precedents strongly suggest that soil scientists would do well to heed Thomson's advice, remain on the path of science, and keep searching for operationally well thought out approaches to the solution of the numerous challenges we face related to soil management, as arduous and daunting as this path may seem at the moment.

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## DATA AVAILABILITY STATEMENT

No new data were generated during the writing of this commentary.

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