The soil quality concept as a tool for exposing values in science and promoting sustainability considerations

Per Schjønning[1]

Introduction

In the developed and industrialized countries, modern agriculture has fulfilled its primary goal of providing adequate and reliable sources of food of good quality, and even more so as witnessed by surplus production and subsidized export of agricultural products. This has contributed to a switch in societal concerns from sheer productivity to sustainability of agriculture, including the effects of production methods on the environment, the diversity of the natural flora and fauna, the welfare of domestic animals, and on the soil resource itself. The quality of air, water and - as yet to a minor extent - soil has come more into focus. Almost every aspect of modern agriculture is now under scrutiny from concerned producers, environmentalists and consumers, from researchers and government as well as non-governmental organizations, and agricultural sustainability is on the agenda of most political movements and parties.

This development has increased the demand for scientifically based solutions that incorporate a wider range of aspects. Scientists have been involved in problem solving and development in the society for centuries but the pressure from society for a pro-active role of science is much more pronounced than a few years ago. Bouma (2001b) denotes the present-day community a network society and urges soil scientists to take active part in 'negotiations' with stakeholders in society. More specifically, he suggests 'research chains' of scientists and stakeholders in order to optimize the implementation of scientific results in land use planning. However, many (soil) scientists are reluctant to take part in such work and claim that science (and hence scientists) should not be involved in value-laden discussions on sustainable development. The present paper deals with some basic issues on values in science. It is crucial that any (soil) scientist realizes how his/her personal opinions and priorities influence his/her research. The soil quality concept offers itself as a tool in this exercise. Many of the considerations presented here are derived from a recent editorial work on a book on soil quality (Schjønning *et al*., 2004).

Descriptive and prescriptive science

Typically, scientists in ecology, geography and other classical scientific disciplines perceive soil as an ecosystem component, and their approach is descriptive and observational in nature. Agricultural researchers, on the other hand, are concerned primarily with the production of food and fibre, and perceive soils mainly as media to support plant growth. Fertility trials, crop rotation studies, tillage experiments, etc., have provided the basis for an increasing productivity. Thus, researchers involved in agricultural sciences are accustomed to produce prescriptions with the clear aim of increasing yields. Ellert *et al.* (1997) advocated a combination of the conceptual/descriptive approaches of ecologists and the quantitative/prescriptive approaches of agronomists. I concur in this opinion, and call attention to the importance of this for organizations as the European Society for Soil Conservation (ESSC). Our knowledge of soil degradation processes is of no need for soil conservation issues if we do not address the management options to combat the degradation.

Soil quality as a technical concept

Numerous publications addressing 'soil quality' have appeared over the last decade. Most papers assign specific soil attributes to the term (e.g. organic matter content, structural stability, and microbial activity). I.e., the soil quality term is often used unreflectively for a vast number of soil characteristics. Also Carter (2002) noted that most studies are purely descriptive. This approach is typical for classical ecologists and geographers. In order to make this approach operational, much focus has been on soil quality *indicators*, hoping that a collection of such indicators may fully classify the quality of some specific soil. Larson and Pierce (1991) suggested a *minimum data set* to describe the quality of a soil. This data set should consist of a number of indicators describing the quality/health of the soil. Using an analogue to human medicine, reference values for each indicator would set the limit for a healthy soil (Larson and Pierce, 1991). The use of indicators has been widely discussed in the literature on soil quality (e.g. Doran and Jones, 1996). Seybold *et al.* (1998) and Sojka and Upchurch (1999) stressed the difficulty in dealing with the 18-20.000 soil series occurring in the USA. Considering the diverse agricultural uses of soils (e.g. growing different crops with dissimilar soil requirements) and the different optima associated with each specific use, Sojka and Upchurch (1999) emphasized *understanding* rather than *rating* of the soil resource. The use of soil quality indicators is even more problematic, when they are indexed (e.g. to range between 0 and 1). One reason is that indexing effectively hides all mechanistic details and reduces a complex soil property/function to a naked value. Another is the fact that judgements on good/poor made by the scientist are embedded in the term.

[1]Department of Agroecology, Danish Institute of Agricultural Sciences, Research Center Foulum, P.O. Box 50, DK-8830 Tjele, Denmark; Telephone: +45 8999 1766; Telefax: +45 8999 1719;
E-mail: Per.Schjonning@agrsci.dk

Confining the soil quality term to a technical denominator of soil properties, indicators and indices is in my opinion both unambitious and – more importantly – even harmful because unreflected societal priorities and personal values are embedded in the term. In consequence, I suggest that the term should be used only in combination with considerations of sustainability issues. Before elaborating on this approach, it is necessary to reflect on values in science and their crucial role in communication on soil issues.

The cognitive context and the reflexive objectivity

Agricultural research is an applied science with the main objective to improve production methods and develop production systems. In consequence, agricultural science influences its own subject area, agriculture, in important ways (Lockeretz and Anderson, 1993). In general, science that influences its own subject area is defined as *systemic science* (Alrøe and Kristensen, 2002). The fact that science plays a pro-active role in the world that it studies makes the criterion of objectivity as a general scientific ideal less straightforward. It is important that the scientist is able to view her- or himself as part of the system (self-reflection). This ability to take an 'objective' stance but at the same time being aware of the intentional and value-laden aspects of science is denoted *reflexive objectivity*, and the framework in which these reflections take place is labelled the *cognitive context* (Alrøe and Kristensen, 2002). The cognitive context may be divided into three: the observational, the societal, and the intentional. The observational context includes the actual methodological aspects of the research, the societal context is the group or segment for which the research is relevant, and the intentional context is the goals and values employed.

In this paper, only a few remarks will be added to the above definition (please consult Alrøe and Kristensen (2002) for a more thorough introduction to the cognitive context and the reflexive objectivity). The relevance of the scientific work depends on the *societal context* pervading at the time of the study. There is no 'universal' science that is independent of social context. When pesticides became available to farmers in the mid 20th century, the most relevant task for agricultural researchers was to optimise their use for maximum production and minimum costs. Today's scientists are engaged in studies of the detrimental rather than the beneficial effects of pesticides (e.g. ground water pollution, bioaccumulation, side-effects on non-target organisms). The example serves to illustrate that the societal context has changed dramatically during the period discussed here. The *intentional context* in science has to do with values and goals for the specific research group or scientist. Sojka and Upchurch (1999) gave a critical review on the concept of soil quality. Some of their concerns were abstracted as 'we are .... reluctant to endorse redefining the soil science paradigm away from the value-neutral tradition of edaphology and specific problem solving to a paradigm based on variable, and often subjective societal perceptions of environmental holism'. That is, the authors support the classical understanding of objectivity in science. In their paper, however, they draw the attention to articles dealing with different aspects of soil quality and raise the query whether a high biodiversity in soil is more valuable than animals at the other end of the food chain. I interpret their statement as giving a high production of foods (higher animals) a higher priority than a high biodiversity in the soil. This is of course a legitimate standpoint, but my point is that this opinion also reflects an 'intention' or a 'value/goal'. Awareness of these values is what the reflexive objectivity is all about.

Soil quality as a cognitive concept

The soil quality term emerged in North America (Alexander, 1971; Warkentin and Fletcher, 1977). Despite an early, intense discussion in the USA (e.g. Allan *et al.*, 1995; Karlen *et al.*, 1997) and the governmental support for an institute addressing the soil quality concept (Anonymous, 1996), the relevance and impact of the concept are currently being disputed (Sojka and Upchurch, 1999; Karlen *et al.*, 2001; Letey *et al.*, 2003; Sojka *et al.*, 2003; Karlen *et al*., 2003). It appears that this dispute is fuelled largely by the lack of a clear objective for the use of the soil quality concept.

Soil quality is how well soil does what we want it to do'. This statement, extracted from the web-site of the USDA Soil Quality Institute, represents the very essence of the soil quality concept. The statement includes two aspects: 'how well' relates to grading soils (the descriptive approach discussed above), while 'what we want' relates to priority of soil functions. And priorities are based on sustainability considerations, which further are founded in values pervading in the society at the specific time (the societal context) and the opinions of the researcher (the intentional context). What is important in this context is the fact that any evaluation of some property or function in soil necessarily involves values and priorities. The literature cited above clearly illustrates that it is a prerequisite for fruitful communication among scientists as well as between scientists and stakeholders that these values are explicitly stated together with the basic scientific results.

Mans interaction with soil

Blum and Santelises (1994) and Blum (1998) considered the functions and services of soil as related to human activity and grouped them into six categories. Three ecological uses are 1) the production of biomass, 2) the use of soils for filtering, buffering and transforming actions, and 3) the provision of a gene reserve for plant and animal organisms. Three other functions relate to non-agricultural human activities: 4) a physical medium for technical and industrial structures, 5) a source of raw materials (gravel, minerals etc), and 6) a cultural heritage. This classification of man's interest in and interaction with soil may facilitate an operational definition of soil quality: *Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation* (Allan *et al*., 1995; Karlen *et al.*, 1997). Keeping the above reflections on the cognitive context in mind, the exercise of soil quality evaluation thus involves explicit judgement of which soil conditions will fit the sustainability expressions in this definition. This link between soil quality and sustainability is so very important because soil quality should not remain an abstract concept but rather something to be strived for by management (Bouma *et al.*, 1998).

Indicator threshold and management threshold

Threshold was defined by Smyth and Dumanski (1993) as 'levels beyond which a system undergoes significant change; points at which stimuli provoke response'. Thus threshold links to resilience. As an example, Smyth and Dumanski mentioned the threshold for erosion as the level (extent of erosion) beyond which erosion is no longer tolerable (in order to maintain sustainability). Thus, thresholds are values of a variable beyond which rapid, often exponential, negative changes occur (Pieri *et al.*, 1995). Because of their intimate association with resilience, focus should be on *thresholds* rather than on *references*, *baselines* or *benchmarks*, often employed in the literature on soil quality indicators.

This paper advocates a shift from *assessing* soil quality to *managing* soil quality. Of course management cannot be addressed without evaluating soil attributes (i.e. indicators) but putting the focus on the effects of management may establish a more relevant foundation for the soil quality concept. When the common knowledge on soil functions and properties (including indicator thresholds) is combined with that derived from studies on the effects of specific management tools, the potential outcome can be *management thresholds*, i.e. the most severe disturbance any management may accomplish without inducing significant changes towards unsustainable conditions (Schjønning *et al*., 2004). Let me give an example: regarding soil acidity, soil pH is a soil quality indicator for which a threshold can be established, while the rate of liming (e.g. kg $CaCO_3$ ha^{-1} $year^{-1}$) required to maintain the pH at some prescribed level represents the management threshold.

Science, scientists and society

Bouma *et al.* (1998) advocated a 'research chain' for implementation of scientific results in decisions on management and land use. This would imply methodical steps in a process of identifying, selecting, resolving and presenting the soil quality problem and the knowledge gained. This 'chain'-approach should be performed by an interdisciplinary group of researchers and stakeholders. A step-by-step increase in complexity of succeeding research chains may further improve the quality of decisions on land use (Bouma, 2001b). At the same time, this will optimise the focus and the contribution from all branches of science, both fundamental, strategic and applied research. Bouma (2001b) also mentions the benefits of such procedures in highlighting the key role of soil science in producing optimized solutions to management and planning problems in society. He even claims that a continued passive role of soil scientists is a threat to the mere survival of the profession of soil science!

The reader is encouraged to consult the papers of Bouma for inspiring ideas on this important role of the modern scientist (e.g. Bouma *et al*., 1998; Bouma 2000, 2001ab, 2004). However, the examples of communication problems among scientists mentioned above clearly stresses that first we need a shift in the research paradigm (Fig. 1). Barrett and Raffensperger (1999) speak of 'precautionary science' as an alternative to classical, positivistic science. The precautionary principle is related to and interacts with the sustainability concept. One basic issue of the precautionary principle is 'thoughtful action in advance of scientific proof' (O'Riordan *et al*., 2001), which – from a first sight – is rather difficult to combine with natural sciences. However, this exercise of combining societal concerns and research results is in accordance with the notion 'reflexive objectivity'. The difference between the 'reflexive objectivity' approach suggested by Alrøe and Kristensen (2002) and the 'precautionary science' approach of Barrett and Raffensperger (1999) is the way that values associated to science are treated (Fig. 1). The reflexive objectivity yields an important and explicit differentiation of the specific experimentation on one side and the values and goals associated to the experimentation on the other. In contrast, Barrett and Raffensperger (1999) arrive at a situation very much alike that predominating for the positivistic view of science: values and priorities are closely – and at the end in reality unreflectively – associated with the observations and experiments. This is a big mistake and in my opinion really 'dangerous' for a fruitful implementation of the concerns addressed in the precautionary principle. A new, alternative research paradigm should put explicit considerations on values in science to the activities of scientists by increasing their awareness of the cognitive context. The shift should <u>not</u> retain the mix (read: mess) of specific scientific observations and evaluations of sustainability (Fig. 1). It is important for me to state that the above statements do <u>not</u> include an attitude to the precautionary principle.

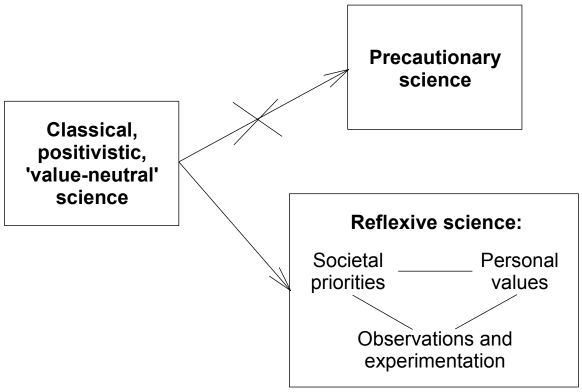

Figure 1. Science is influenced by the societal priorities and personal values of the scientist. The shift from the classical, positivistic research paradigm should take use of the explicit considerations on societal priorities and personal values offered by the reflexive objectivity approach ('reflexive science', lower box). The notion of 'precautionary science' is dissuaded because this paradigm keeps the (unreflected) mix of observations and values also found in the positivistic approach. Consult text for details.

Summary and conclusions

The term soil quality has mainly been used as a technical concept for grading soils. It is important that the values and goals in soil use planning and soil management are explicitly stated and related to the soil quality indicators. Such a cognitive soil quality concept may facilitate the urgent need of soil scientists to interact with stakeholders in the society. Useful approaches for such exercises have been proposed in the literature. A shift in research paradigm away from the classical, positivistic, 'value-neutral' approach is, however, a prerequisite for a fruitful outcome of this endeavour. The reflexive objectivity is a valuable tool in differentiating the basic scientific observations from societal priorities and personal values of the scientist. Other suggestions of associating 'post-positivistic-science' societal priorities to observations and experiments (e.g., 'precautionary' science) are strongly dissuaded. The suggested increase in focus on sustainability-based decisions on soil management induces a recommended search for 'management thresholds' rather than the more descriptive 'soil quality indicator benchmarks/thresholds'. I strongly recommend the ESSC to increase its activities on prescriptive and management-oriented research and in this endeavour make use of the proposals given above.

References

Alexander, M. (1971) Agriculture's responsibility in establishing soil quality criteria. In: *Environmental Improvement – Agriculture's Challenge in the Seventies*. National Academy of Sciences, Washington, D.C., pp. 66-71.

Allan, D.L., Adriano, D.C., Bezdicek, D.F., Cline, R.G., Coleman, D.C., Doran, J.W., Haberen, J., Harris, R.G., Juo, A.S.R., Mausbach, M.J., Peterson, G.A., Schuman, G.E., Singer, M.J. and Karlen, D.L. (1995) SSSA Statement on soil quality. In: Agronomy News, June 1995, ASA, Madison, WI, p.7.

Anonymous (ed.) (1996) *The Soil Quality Concept*. The Soil Quality Institute, Natural Resources Conservation Service, United States Department of Agriculture, 89 pp.

Alrøe, H.F. and Kristensen, E.S. (2002) Towards a systemic research methodology in agriculture. Rethinking the role of values in science. *Agriculture and Human Values* 19, 3-23.

Barrett, K. and Raffensperger, C. (1999) Precautionary science. In: Raffensperger, C. and Tickner, J.A. (Eds.) *Protecting public health & the environment. Implementing the precautionary principle*. Island Press, Washington, D.C., pp. 106-122.

Blum, W.E.H. (1998) Basic concepts: Degradation, resilience, and rehabilitation. In: Lal, R., Blum, W.E.H., Valentine, C. and Stewart, B.A. (eds.) *Methods for Assessment of Soil Degradation*. CRC Press, Boca Raton, New York, pp. 1-16.

Blum, W.E.H. and Santelises, A.A. (1994) A concept of sustainability and resilience based on soil functions: the role of ISSS in promoting sustainable land use. In: Greenland, D.J. and Szabolcs, I. (eds.) *Soil Resilience and Sustainable Land Use*. CAB International, Wallingford, UK, pp. 535-542.

Bouma, J. (2000) The land quality concept as a means to improve communication about soils. In: Elmholt, S., Stenberg, B., Grønlund, A. and Nuutinen, V. (eds.) *Soil Stresses, Quality and Care*. Proceedings from NJF Seminar 310, 10-12 April 2000, Ås. DIAS Report, Plant Production No. 38, Danish Institute of Agricultural Sciences, Foulum, pp 1-14.

Bouma, J. (2001a) The role of soil science in the land use negotiation process. *Soil Use and Management* 17, 1-6.
Bouma, J. (2001b) The new role of soil science in a network society. *Soil Science* 166, 874-879.
Bouma, J. (2004). Implementing soil quality knowledge in land-use planning. In: Schjønning, P., Elmholt, S. and Christensen, B.T. (Eds.) *Managing Soil Quality: Challenges in Modern Agriculture*. CABI Publishing, Wallingford, UK, pp. 283-296.
Bouma, J., Finke, P.A., Hoosbeek, M.R. and Breeuwsma, A. (1998) Soil and water quality at different scales: concepts, challenges, conclusions and recommendations. *Nutrient Cycling in Agroecosystems* 50, 5-11.
Carter, M.R. (2002) Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. *Agronomy Journal* 94, 38-47.
Doran, J.W. and Jones, A.J. (eds.) (1996) *Methods for assessing soil quality*. Soil Science Society of America Special Publication Number 49.
Ellert, B.H., Clapperton, M.J. and Anderson, D.W. (1997) An ecosystem perspective of soil quality. In: Gregorich, E.G. and Carter, M.R. (eds.) *Soil Quality for Crop Production and Ecosystem Health*. Developments in Soil Science 25, Elsevier, Amsterdam, pp. 115-141.
Karlen, D.L., Andrews, S.S. and Doran, J.W. (2001) Soil quality: Current concepts and applications. *Advances in Agronomy* 74, 1-40.
Karlen, D.L., Andrews, S.S., Weinhold, B.J. and Doran, J.W. (2003) Soil quality: Humankind's foundation for survival. *Journal of Soil and Water Conservation* 58, 171-179.
Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F. and Schuman, G.E. (1997) Soil quality: A concept, definition, and framework for evaluation. *Soil Science Society of America Journal* 61, 4-10.
Larson, W.E. and Pierce, F.J. (1991) Conservation and enhancement of soil quality. In: *Evaluation for Sustainable Land Management in the Developing World.* Int. Board for Soil Res. and Management, Bangkok, Thailand, pp. 175-203.
Letey, J., Sojka, R.E., Upchurch, D.R., Cassel, D.K., Olson, K., Payne, B., Petrie, S., Price, G., Reginato, R.J., Scott, H.D., Smethurst, P. and Triplett, G. (2003) Deficiencies in the soil quality concept and its application. *Journal of Soil and Water Conservation* 58, 180-187.
Lockeretz, W. and Anderson, M.D. (1993) *Agricultural Research Alternatives*. University of Nebraska Press, Lincoln, NE, USA, 239 pp.
O'Riordan, T., Cameron, J. and Jordan, A. (eds.) (2001) *Reinterpreting the Precautionary Principle*. Cameron May Ltd., London, UK.
Pieri, C., Dumanski, J., Hamblin, A. and Young, A. (1995) *Land Quality Indicators*. World Bank Discussion Papers 315, The World Bank, Washington, D.C., USA, 63 pp.
Schjønning, P., Elmholt, S. and Christensen, B.T. (Eds.) (2004) *Managing Soil Quality: Challenges in Modern Agriculture*. CABI Publishing, Wallingford, UK, 368 pp.
Seybold, C.A., Mausbach, M.J., Karlen, D.J. and Rogers, H.H. (1998) Quantification of soil quality. In: Lal, R., Kimble, J.M., Follett, R.F. and Stewart, B.A. (eds.) *Advances in Soil Science*. CRC Press, Boca Raton, Florida, USA, pp. 387-404.
Smyth, A.J. and Dumanski, J. (1993) *FESLM: An International Framework for Evaluating Sustainable Land Management*. World Resources Reports 73. Land and Water Development Division, FAO, Rome, 77 pp.
Sojka, R.E. and Upchurch, D.R. (1999) Reservations regarding the soil quality concept. *Soil Science Society of America Journal* 63, 1039-1054.
Sojka, R.E., Upchurch, D.R. and Borlaug, N.E. (2003) Quality soil management or soil quality management: Performance versus semantics. *Advances in Agronomy* 79, 1-68.
Warkentin, B.P. and Fletcher, H.F. (1977) Soil quality for intensive agriculture. In: *Proc. Int. Sem. on Soil Environ. and Fert. Manage. in Intensive Agric*. Soc. Sci. Soil and Manure, Natl. Inst. of Agric. Sci., Tokyo, pp. 594-598.