LAND QUALITY AND LAND USE INFORMATION

– IN THE EUROPEAN UNION –

GERGELY TÓTH AND TAMÁS NÉMETH (EDS.)

KESZTHELY
2011.

The international conference on ’Land Quality and Land Use Information in the European Union’ was held on 26-27 May 2011 in Keszthely, Hungary.

Organised by the:
Hungarian Academy of Sciences
University of Pannonia
European Commission
(Joint Research Centre, DG Environment, Eurostat)

In association with the:
Hungarian EU presidency in 2011

Under the high patronage of:
Ministry of Rural Development, Hungary

Publishing Details

European Commission, Joint Research Centre
Institute for Environment and Sustainability

The mission of the JRC-IES is to provide scientific-technical support to the European Union's policies for the protection and sustainable development of the European and global environment.

Contact information

Name: Gergely Tóth
Address: Via E. Fermi 2749; I-21027 Ispra, Italy
E-mail: gergely.toth@jrc.ec.europa.eu
Tel.: +390332786483 Fax: +390332786394
http://ies.jrc.ec.europa.eu/ http://www.jrc.ec.europa.eu/

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How to obtain EU publications

JRC 61094
EUR 24590EN 'Land Quality and Land Use Information in the European Union'
Catalogue Number LB-NA-24590-EN-C
ISBN 978-92-79-17601-2
ISSN 1018-5593
doi: 10.2788/40725

Luxembourg: Publications Office of the European Union

Printed in Hungary
By Ziegler-nyomda, Keszthely

Soil quality: a step back in land evaluation

J.R. Olarieta, R. Rodríguez-Ochoa and E. Ascaso

Abstract

The objective of this paper is to discuss the literature on soil quality evaluation (SQ) with the background of previous efforts in the field of the assessment of soils in relation to land use, and particularly the FAO Framework for land evaluation (FF). We argue that SQ is based on a superficial definition of land use and specially its socio-economic aspects, that it neglects the concept of 'land' and therefore provides an incomplete picture, that it does not provide a explicit assessment of the sustainability of the land-use systems, and that it reproduces the mistake of the FF of trying to aggregate all the aspects of these systems into a single index or class. We conclude that SQ is conceptually and methodologically inferior to the FF, and certainly does not provide a new paradigm for the analysis of land-use systems or soil resources.

Introduction

Soil quality evaluation (SQ) has become the dominant keyword in the literature on the subject of the relation between soils and land uses, substituting for land evaluation (LE) as the framework within which such relationships are studied. Even though both approaches co-habited for some years, LE has mostly disappeared from the literature in favour of SQ. It is probably not just a coincidence that the first books developing and applying SQ (Doran et al., 1994) were published at a time when many authors were criticising the “poor quality and little relevance of many land evaluation exercises” (Rossiter, 1996) and even defining the FAO Framework for Land Evaluation (FF) as “obsolete” (Van Diepen et al., 1991; Van Ranst, 1996).

But even though both approaches seek to analyze the relations between soils and land-use, the literature on SQ very rarely acknowledges previous efforts in this field, and frequently mistakes the concepts and methodologies proposed by LE. Karlen et al. (1997) and De la Rosa (2005) suggest that the difference between land evaluation and soil quality assessment is the failure of the former to consider the biological properties of soils. While it is certainly true that most LE exercises do not include such properties, in all probability this was the result of the inadequate knowledge about these properties years ago, as there is nothing in the FF, for example, against considering them. Furthermore, some authors (e.g. Singer and Ewing, 2000; Bone et al., 2010) mistakenly define the concept of 'land quality' as proposed in the FF as somehow similar but broader than that of 'soil quality'. But the latter would be rather equivalent to the 'suitability' concept of the FF, while a 'land quality' as defined in the FF is similar to an 'indicator' as used in the SQ literature.

Various authors have argued the case against SQ (Sojka and Upchurch, 1999; Letey et al., 2003) on the basis of:

- the need to specify the use for which the soil quality is being assessed,
- the failure to integrate the various functions performed by soils,
- the subjectivity involved in the concept of SQ, and in the choice, scoring and arithmetic manipulation of indicators.

We will argue that most of those problems, and others, are the result of the SQ literature ignoring previous efforts and mistakes in the assessment of soils in relation to land use, namely the FAO Framework. We therefore discuss the concept of soil quality and its use in the literature in relation to some of the principles of the FF:

- its abandonment of the concept of 'land',
- its neglect of the concept of 'land use' and therefore of its socio-economic aspects,
- the lack of an explicit assessment of the sustainability of the land-use system,
- as a result, the preconceived and subjective judgement of SQ.

The abandonment of the concept of 'land'

The use of the term "soil quality" in the various systems of assessment is misleading because:

- some of these systems include indicators which are not related to soils, but to the broader concept of "land" as defined in the FF. For example, the Visual Soil Assessment method (VSA) developed in New Zealand (Shepherd, 2000) includes "surface relief" and the Muencheberg Soil Quality Rating (MSQR; Mueller et al., 2010) includes indicators such as "slope and relief", "flooding", and "exposure to wind",

- if only soil indicators are included, then the assessment system is misrepresenting the role of soils because all the functions they perform are influenced to some extent by land characteristics such as geomorphology, climate, etc. Furthermore, in these cases only some soil characteristics, mostly representing the upper few centimetres of the soil, are considered, and even the soil type is not clearly defined, or if defined, the results are not clearly separated for the various types of soils involved (e.g. Andrews et al., 2002a).

- Hardly any paper on SQ considers the influence of non-soil land characteristics, even though, quite rightly, Sparling and Schipper (2002) state that "both [profile descriptions and site characterizations] are necessary…for meaningful soil quality assessment". But most SQ assessments alienate the topsoil from the whole soil profile and from the land unit where it is embedded. From a pragmatic point of view, setting the soil within its land unit is important because:

- soil characteristics are the result of the interplay between the soil forming factors and therefore the "dynamic" soil properties are deeply related to the "inherent" soil properties (Schipper and Sparling, 2000; Girvan et al., 2003; Wilson et al., 2008; Cotching and Kidd, 2010).

- those characteristics of the land unit that are not directly related to soils (e.g., climate, slope) may be much more important in determining land use than soil characteristics themselves (Olarieta and Rodríguez-Ochoa, 2004; Olarieta et al., 2008a). Such land characteristics are of fundamental importance also in determining the results of the land-use system (e.g, productivity, erosion) (Blaschke et al., 1992; Page-Dumroese, 2000; Olarieta et al., 2000, 2006)

Furthermore, soil quality assessments are based, in many cases, on scores of individual soil indicators which are arithmetically lumped into an index, and therefore the interactions between these indicators are mostly left implicit.

The neglect of land use

If "a soil quality monitoring system is critical to understanding how the soil resource is being affected by land use" (Griffin and Broos, 2009, cited by Cotching and Kidd, 2010), then it is hard to understand how any meaningful conclusion can be obtained without analyzing land use together with soils. But it is common practice in the SQ literature to do so (e.g., Halvorson et al., 1996; Laird et al., 2010). Nevertheless, in this respect most exercises on SQ assessment fall into two groups: they either work at a general scale comparing some soil variables between broadly-defined land uses (e.g., forestry, agriculture, pasture) (e.g., Trasar-Cepeda et al., 1998; Schipper and Sparling, 2000; Rodríguez et al., 2002; Wander et al., 2002; Miralles et al., 2009; Taylor et al., 2010), or they analyse the effect on some soil characteristics of various management systems for the same crop or rotation (e.g., Karlen and Stott, 1994; Andrews et al., 2002a; Reganold et al., 2010). Therefore, it is difficult in many cases to interpret whether the objective of SQ assessments is to define the capacity of a soil for use, as expressed in the definitions of SQ, or to evaluate the effects of use on soil.

And again, there is a contradiction in using as indicators of soil quality outputs and/or capital inputs of the broader land-use system, which depend not only on soil characteristics, but also on the socio-economic system involved and on the land unit concerned, as we have already discussed. For example, the VSA method includes 'production costs' and 'crop yields' as indicators, the Wisconsin Soil Health Scorecard (Romig et al. 1996, cited by Wander et al., 2002) uses indicators such as 'erosion' and 'surface cover', and Janvier et al. (2007) also propose 'plant health' as an indicator.

But the main problem is, in a similar fashion to most LE exercises, that we are mistaking 'technology' for 'land use'. While Letey et al. (2003) propose that soil quality should specify "soil use as the criteria for evaluation", we suggest that the evaluation criteria should be the performance objectives of the land use system as defined by the farmer or the social group involved. Land use is the means through which land managers in the first instance, and human communities at various scales (local, regional, national,..), seek to realize various objectives. Therefore, the 'functions' expected from soils and the degrees to which they are expected to be fulfilled are defined by those various scales of human organization. Land use is strongly influenced by factors such as farm size, farmers' preferences, and market prices of inputs and produce, and in many instances much more so than by soil or land factors (Ravnborg and Rubiano, 2001). Andrews et al. (2002b) implicitly recognize this fact when they state that "the [conventional] farmers [involved in their experiment] were unwilling to accept the perceived risk of lost revenue associated with reducing synthetic fertilizer inputs".

The neglect of sustainability assessment

The literature on SQ seeks to address the analysis of the sustainability of the soil resources, but it is hardly explicit about it. The SQ indexes obtained are aggregates of various indicators and while some of these may address the sustainability of land use, their information is lost in the final index. Furthermore, sustainability is a multi-faceted issue that can hardly be compressed into a few indicators. One of the strong points of SQ exercises has been the systematic use of soil biological properties, but excessive reliance on these properties at the expense of other 'inherent properties' of soils may fail to provide the complete picture. Microbial properties are very sensitive to land-use change but recover very quickly after disturbance while other whole-profile variables may take much more longer to return to pre-disturbance levels (Blaschke et al., 1992; Sparling et al., 2003).

But SQ studies do not provide an explicit evaluation of the underlying reasons for (un)sustainability because they fail to assess the balance between inputs and outputs of the land-use system. Comparisons with 'pristine' or 'natural' soils are flawed in this sense because the high correlation between land unit and land use (Olarieta and Rodríguez-Ochoa, 2004) prevents any meaningful comparison as detected differences in soil variables may be the result of initial differences, of differences produced by land uses of the past, or indeed of those produced by present land use.

And once again SQ assessments fall into the methodological confusion of using indicators that are actually outputs of the whole land-use system. For example, the VSA method includes 'degree of soil erosion' as an indicator and the MSQR system includes processes, such as acidification, and salinization which also very much depend on land use.

The subjectivity in the evaluation of 'soil quality'

In many cases in the SQ literature, there is no explicit assessment of how the indicators chosen, nor the threshold values used, are related to some desired function (e.g. Halvorson et al., 1996), and therefore, the whole process of indicator scoring and integration into indexes is subjective. As Andrews et al (2002b) put it, "we *assume* that higher index scores meant better soil quality or greater performance of soil functions" (emphasis added). Similarly, increases or decreases in the values of the indicators are considered to be related to 'better' or 'worse' quality soils without any justification (e.g. Miralles et al., 2009; Laird et al., 2010), with the result that according to the set of indicators used the pattern of soil quality among land uses may turn upside down in some cases(e.g., Miralles et al., 2009).

Lilburne et al. (2002) quite correctly state that "the interpretation of soil quality is a value judgement based on human demands on soil for a selected land use". They consider that the target ranges for indicators should "strike the right balance between maximizing agronomic production and minimizing environmental impacts". But they fail to ask the questions that are due after such statement:

- what constitutes a 'right balance' and who defines it,
- why 'maximize' production and 'minimize' environmental impacts.

'Maximizing' production is a recurrent value criterion in the literature, including both supporters (Lilburne et al., 2002; Shukla et al., 2004) and critics of SQ (Letey et al.,2003), with the implicit assumption that higher productivity is "better", regardless of who defines such objective and whether it should be achieved at any cost in terms of inputs or in terms of costs to other functions.

In relation to who defines the right balance, one answer in the SQ literature has been relying on some group of 'experts' or setting a standard (Lilburne et al., 2002). But as we have previously discussed, direct land users have specific aims, objectives and constraints in relation to their use of land, and other members of the population ideally define the social aims through the various land-use policies. Therefore, it is from these set of functions that a realistic balance should be defined.

Andrews et al. (2002a), although basically as a side issue, consider specific management goals, but assume that they are identical for various production systems (i.e., conventional, low input, and organic). But it is precisely the search for management goals different from those of conventional agriculture that has been the basis of the development of organic agriculture. Again, and in similar fashion to most of the previous literature on land evaluation, the land use is mistakenly reduced to the technology, and the actual objectives, goals and constraints of land managers not considered.

What is the final product?

The final result obtained in some SQ evaluations is not some integrative index or concept, but simply a collection of soil properties that are determined and compared mostly among different broadly-defined land uses with no further elaboration of their influence on land use objectives (e.g., Sparling and Schipper, 2002; Laird et al., 2010: Reganold et al., 2010; Miralles et al., 2009; Taylor et al., 2010).

But in those cases when such index is obtained, the issue is that it provides no new information, disguises the truly useful one, and is necessarily based on some subjective value judgement. As Wander et al. (2002) reflect, farmers “expressed no interest [in generating an overall SQ score]…Instead, they indicated a preference for information capturing the tradeoffs or complexities of their soil”. The index proposed by Karlen and Stott (1994), for example, includes an indicator for ‘resisting degradation’ and another for ‘supporting plant growth’ which are added up, along with other indicators. But what is the meaning of an index mixing up such indicators? What would be its interpretation? Which action is the farmer supposed to take? Knowing that his soil quality index is 0.73, is he supposed to use more manure to increase resistance to degradation? or increase fertiliser use to improve plant growth?.

In this respect, SQ reproduces the same mistake as previous systems of land evaluation, whether the final product is called 'land suitability”, 'land capability', or 'soil quality'. Such aggregate index or classification, as any other measured in a single metric (e.g., monetary analysis, energy analysis, ecological footprint) will always require a value judgement in order to translate all the inputs and outputs of the land-use system to that metric (Olarieta et al., 2000), and certainly will not provide an appropriate assessment of the soil resources (Olarieta, 2000; Olarieta et al., 2008b).

Conclusions

Conceptually and methodologically, Soil Quality is a step back in the scientific assessment of soils in relation to land use, certainly in relation to the FAO Framework for Land Evaluation, and, therefore, it does not represent any 'new paradigm'. Indeed, some SQ applications are similar to land capability classifications (e.g., Joubert, 2001) or parametric indices (e.g., the MSQR and VSA systems), so much so that

Singer and Ewing (2000) include all previous parametric systems and land capability classifications as 'indices of soil quality'.

Methodologically, the various proposals put forward up to now in the literature on SQ are much poorer that the FAO Framework. While some starting points are similar (e.g., the 'soil quality indicators' are equivalent to 'land characteristics' and 'land qualities', and the 'minimum data sets' are similar to the 'diagnostic characteristics' (Beek and Laban, 1981)), in very few cases does the SQ literature acknowledge the need for a thorough definition of the land use type and its socio-economic context, for the assessment of all inputs and outputs of the land-use system, or for economic analyses or environmental impact assessment.

The Soil Quality literature reproduces the main mistake of the Framework, that is, the aggregation of information concerning widely different aspects of the land-use system (e.g., yields, revenues, pesticide load, soil eroded) into a single class or index. An assessment of all the inputs and outputs of the land-use systems and their spatial variability is the only objective information that results from land evaluation and also the most significant for decision-making.

We believe that these problems with the Soil Quality approach are the result of two basic things. First, different schools within Soil Science remain very much within themselves and seem not to pay much attention to developments proposed by other schools. Hardly any references to the literature on Land Evaluation, which was mostly the result of work in FAO and by European authors, may be found in the literature on SQ, which was originally an effort from authors in the USA. And second, we are not capable of true transdisciplinarity, and getting out of Soil Science and having a walk around Economics seems like an impossible task. We feel comfortable with ‘soil physics’ and ‘soil chemistry’, but not really with, say, ‘soil economics’.

Acknowledgements

We would very much like to thank the reviewer for the helpful comments on a previous version.

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Contact

J.R. Olarieta
Departament de Medi Ambient i Ciències del Sòl
Universitat de Lleida – Spain

Email: jramon.olarieta@macs.udl.cat