Agriculture, Ecosystems and Environment 232 (2016) 179–189

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Soil indicators for sustainable development: A transdisciplinary approach for indicator development using expert stakeholders

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ARTICLE INFO

Article history:
Received 20 April 2016
Received in revised form 29 July 2016
Accepted 4 August 2016
Available online xxx

Keywords:
Sustainable development
Soil
Indicator
Delphi survey technique

ABSTRACT

Sustainable management of soils is needed to accomplish many of the United Nations' Sustainable Development Goals, but it can be problematic in practice as soils are complex and to manage them sustainably requires the co-operation of multiple stakeholders on various level of society. We present the outcome of a transdisciplinary approach towards indicator development, where we created a set of soil indicators for sustainable development with stakeholder group participation from scientists, policy-makers and soil practitioners. The groups evaluated 49 indicators, through a Delphi survey technique, and selected a set of 30 indicators. Of these 14 were common to all stakeholder groups and represented a final set of core soil indicators for sustainable development. The Delphi survey did suffer from high attrition rate and low response rate, especially among the policy makers, which limits somewhat its findings. Nevertheless, the survey illustrated the usefulness of relevant stakeholder involvement in an indicator development process and the role of survey based instruments in aiding the selection of common indicators, whilst showing the different views of stakeholders groups. Given that the stakeholder groups have to consider a multitude of variables and impacts on soil and may have different focus and management goals in mind, a process such as this can serve as a starting point for discussion between stakeholder groups on various levels of governance about how to manage soil sustainably and help to fulfil the UN's Sustainable Development Goals.

1. Introduction

Soils supply us with food and clean water, they recycle nutrients, decompose contaminants, control water fluctuations, sequester and store significant amount of carbon and provide habitats for the largest number of species of any ecosystems on Earth (Science, 2004; Brevik et al., 2016). Owing to the multiple roles soils have in Earth's ecosystems, humans use them extensively and are thus exerting pressures that have resulted in their degradation (European Commission, 2002; Keesstra et al., 2016). In 2008 there were approximately 1.38 billion hectares of arable land worldwide (FAO, 2010) and up to 5 million hectares are lost every year because of degradation. Soil degradation impacts negatively on the multiple functions of soils (Table 1) and in turn affects more than 1.5 billion people in over 110 countries; 90% of which live in low-income countries (Nellemann, 2009).

In the European Commission's Towards a Thematic Strategy for Soils (European Commission, 2002, 2006) eight main threats to soils are listed (Table 2), illustrating that human activities such as agriculture and forestry practices, industrial activities, road building and soil sealing are major causes of degradation (Turbe' et al., 2010).

With a growing world population, the need for food, clean water and biofuels is on the rise. The demand for food and water is expected to increase by 50% and 30% respectively by the year 2030 (Godfray et al., 2010). Soil degradation presents a serious threat to fulfilling this likely increased demand (Bindraban et al., 2012), and as a result the protection and sustainable management of the soil resource becomes even more important.

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http://dx.doi.org/10.1016/j.agee.2016.08.009
0167-8809/

Table 1
Soil functions in Towards a Thematic Strategy for Soils (European Commission, 2002, 2006).

Soil Function Number	Soil functions (SF)
SF1	Food and other biomass production
SF2	Storing, filtering and transformation
SF3	Habitat and gene pool
SF4	Physical and cultural environment for mankind
SF5	Source of raw materials
SF6	Acting as a carbon pool
SF7	Archive of geological and archaeological heritage

Table 2
Soil threats according to the Towards a thematic strategy for soils (European Commission, 2002, 2006).

Soil Threat Number	Soil threats (ST)
ST1	Erosion
ST2	Decline in organic matter
ST3	Soil contamination
ST4	Soil sealing
ST5	Soil compaction
ST6	Decline in soil biodiversity
ST7	Salinisation
ST8	Floods and landslides

1.1. The sustainable development concept

The concept of sustainable development became known in 1987 with the Brundtland Commission's report, *Our Common Future,* and has since then been central to decision-making worldwide (Environment and Development, 1987; MEA, 2005). The 'Brundtland Report' defined sustainable development as development that "*meets the needs of the present without compromising the ability of future generations to meet their own needs*". It centres on the notion of equity, both intra- and intergenerational, and the importance of keeping humanity and its ecological impact within planetary boundaries (UNDESA, 2002; Rockstrom et al., 2009; Steffen et al., 2015).

1.2. Sustainability assessment and indicators

The need for the development of sustainability indicators is clearly set out in Agenda 21 from the Rio UN Summit in 1992 and was taken up by the UN Commission for Sustainable Development (CSD) (Pinfield, 1996). In addition, academics have called for the use of indicators as a means of measuring steps towards sustainability (Bell and Morse, 2008; Easdale, 2016). An indicator demonstrates in what direction something or someone is heading (Ness et al., 2007). By visualizing phenomena and highlighting trends, indicators simplify, quantify, analyse and communicate otherwise complex and complicated information (Warhurt, 2002), and as such they are meant to make complex realities more transparent (Jesinghaus, 1999). Indicators are important tools of sustainability assessment. Sustainability assessment is an iterative, continuing, collaborative process that is an important tool to aid in the shift towards sustainability, helping decision-makers consider the actions that should or should not be taken (UNDESA, 2007). Indicators and assessment tools are therefore essential to reach the various targets and goals relating to sustainable development.

1.3. Sustainable development goals

The United Nations' *Transforming our World: the 2030 Agenda for Sustainable Development* lists 17 Sustainable Development Goals and 169 targets that will stimulate action in critical areas for humanity and the planet until 2030 (United Nations, 2015). Sustainable management of soils has direct relevance for at least half of them and might also be relevant for other goals but in an indirect manner (see Table 1 in Supplementary material). Bouma (2014) and Keesstra et al. (2016) have emphasised the important role of soils in obtaining these goals. It is safe to assume that indicators are needed to report on how sustainably soils are managed in pursuit of the Sustainable Development Goals.

1.4. Soil indicators

Until now indicators for sustainable soil management have mostly been developed within the nature dimension of sustainable development, focusing on the physical, chemical or biological aspects of soils. What has been lacking are the other two dimensions: the social and well-being, and the economic. A plethora of soil indicators for different soil properties, qualities and functions exists in the nature dimension: Arshad and Martin (2002) proposed a minimum data set for soil quality, Marinari et al. (2006) and Fließbach et al. (2007) compared conventional and organic agriculture by using soil properties, and Roldán et al. (2007) used a biological properties of soil approach to compare till and no-till management systems. Rüdisser et al. (2015) proposed linking soil quality indicators with the occurrence of certain soil organism groups and Ritz et al. (2009) looked at national soil monitoring focusing on biological indicators. Muscolo et al. (2015) proposed using biochemical indicators looking at changes in soil organic matter as an early warning system in soil ecosystems. Huber et al. (2008) linked soil indicators directly to soil threats and Thomsen et al. (2012) used soil indicators as chemical stressors in soil systems. These are just a few examples of soil indicators from the literature but as stated before, there is predominance of nature based indicators in the soil sets or frameworks and there is a need to combine indicators from the nature dimension of soil, like soil quality with non-soil biotic, abiotic and socio-economic indicators (Herrick, 2000).

This is the first attempt that we know of that builds a set of soil indicators covering all of the three overarching dimensions of soil sustainable development, using a transdisciplinary approach with active stakeholder participation. In this paper we describe the second stage of developing soil indicators for sustainable development (SIFSD) using a survey based technique involving expert stakeholder involvement.

2. Methods

The complete SIFSD development process is illustrated in Fig. 1. The pre-development aspects, as completed by Jónsdóttir (2011), are indicated in steps 1–5 and that process is not covered in this paper.[1] The pre-development work resulted in 44 theme-based indicators that were used as potential indicators for a Delphi survey that took place in Iceland. Steps 6–8 relate to the Delphi survey outcomes and are the main focus of this paper. Steps 9–10 are only implemented when the indicators are applied to a specific study location and are therefore beyond the scope of this paper.

2.1. The Delphi survey technique

The Delphi survey technique is a vehicle for stakeholder engagement. The technique has been used to address sustainable development issues in many diverse sectors, including mining (Azapagic, 2004), forestry (Sharma and Henriques, 2005), transportation (Mihyeon Jeon and Amekudzi, 2005), environmental

[1] Information on the pre-development work can be found at: http://skemman.is/stream/get/1946/8865/24238/1/jonsdottir_msc_2011.pdf