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A method to assess ecosystem services developed from soil attributes with stakeholders and data of four arable farms

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ABSTRACT

Ecosystem-service indicators and related accounting units are crucial for the development of decision frameworks for sustainable land management systems. With a management concept using ecosystem services, land-use expectations can be linked to quantifiable soil features in a defendable and transparent way. A method to define a set of site-specific ecosystem services and indication system for quantification was set-up and run. First, we interviewed a wide group of land users profiting from ecosystem services of the soil at four arable farms in the polder Hoeksche Waard (S–SE of Rotterdam, the Netherlands). Subsequently, site-specific ecosystem services were defined and weighted according to land use expectations at different spatial and temporal scales. Second, a practical set of indicators was taken from 'Best Professional Judgment' and used to quantify the performance of the ecosystem services for these four farms. The indicators were derived from biotic and abiotic soil parameters. The performance of ecosystem services was related to a reference situation (MEP: maximum ecological potential) with the same land use and soil type combination (i.e., arable fields on silt loam) taken from the database of our national soil survey. In many cases, the performance of ecosystem services was relatively poor if compared to MEP. However, the performances of natural attenuation and/or climate-related services were better. In addition, the different management of these farms (i.e. conventional, intensive and organic farming) was reflected in the performance of the ecosystem services of their soils. Third, land management measures to improve the targeted ecosystem services were incorporated in the outlined method, but not worked out with illustrative field data in this study. Together with concordant data, we show opportunities for a quantification of ecosystem services to improve land-users' awareness and to assess management sustainability.

1. Introduction

The complex interactions between policy and management demanding for a rapid and efficient instrumentation to assess land-use sustainability remain among the key points for the coming years, regardless of the decision level (i.e., nationally, continental—in our case: EU, and globally). Therefore the issue is covered by the EU thematic strategy for soil protection (European Commission, 2006), the Millennium Ecosystem Assessment (2005) and 'The Economics of Ecosystems and Biodiversity' (TEEB, 2010). These frameworks describe soil degradation processes and aim to refer to sustainable land management in order to convert the profit from soil into a mutual benefit for land users and society. Thus, the denominator 'soil quality' in meaningful aspects for society had to be adopted into any applied ecology view, and ecosystem services were introduced (Costanza et al., 1997; Dominati et al., 2010; Millennium Ecosystem Assessment, 2005).

On a specific spot there is always a series of independently available ecosystem services, each of them relevant at a different complexity level and therefore attractive for a different group of land users or beneficiaries. Consequently for a certain spot on earth, there is always a set of various land users that have different interests for the local soils. These land users are not necessarily united like most land managers, since land management and ecosystem services are active at different spatial and temporal scales. Through the recognition of the ecosystem services, however, it is possible to visualize the costs of land management and the soil revenues including the benefits in one transparent way for all stakeholders. Sustainable management of ecosystem services becomes easier to implement after balancing of the investments and interests of stakeholders at a specific place.

Visualization can be achieved by the use of a three-step instrument (Fig. 1) as: 1. Weigh the relevance of each ecosystem service as a part of the total system, and 2. Quantify the ecosystem services at a place.

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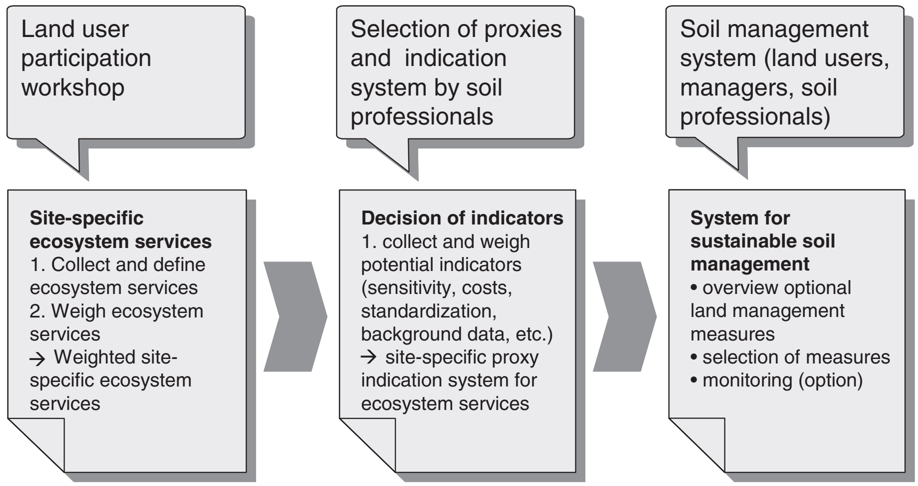

Fig. 1. Schematic process for working with ecosystem services. Stakeholders and professionals are consulted at different positions in the process.

This might ultimately be followed by a system of payments between providers (owners or managers) and users of ecosystems, as discussed by Petheram and Campbell (2010) when measures towards sustainable land management have to be considered (step 3).

With respect to step 1, stakeholder participation workshops should be organized for collecting each conceivable site-specific ecosystem service. This initially unrestricted set should be structured and accurately defined for further processing in a quantitative manner. To be practical in our common attempt to keep the discussion sharp and focused, neither too few (e.g. less than five) nor too many (e.g. more than twenty) site-specific ecosystem services should be defined (Haygarth and Ritz, 2009). Only then, this practical set of ecosystem services can be evaluated for each temporal and spatial scale, and finally be integrated into a (possibly weighted) set. It is recommended to always initiate such a discussion with a representative group of assigned land users for the most appropriate and complete set of site-specific ecosystem services, starting for instance with the list of the Millennium Ecosystem Assessment (2005) or other listings (e.g. Dominati et al., 2010; Rutgers et al., 2009).

With respect to step 2, we seem to be still in a state of imperfect knowledge (Boyd, 2007; Kontogianni et al., 2010; Luck et al., 2009). From the scientific point of view, the knowledge for a quantitative assessment of ecosystem services falls behind the high criteria for scientific quality. So far, many ecosystem services are poorly defined and cannot straightforwardly be linked to the quantifiable soil attributes. Nevertheless there were some attempts to quantify ecosystem services. Recently, Dominati et al. (2010) proposed a framework to quantify ecosystem services through the well-known physical, chemical and biological attributes of the soil. Only some of these linkages were explored (Van Eekeren et al., 2010). Consequently, mechanistic links of any of such an attribute become potentially useful for quantification of ecosystem services in models, e.g. earthworm activity seems to be strongly related to soil structure (e.g. Jongmans et al., 2001). In order to develop right now site-specific instruments for quantification of the complete set of ecosystem services using the imperfect knowledge, various experts need to be consulted for linking system attributes to the respective ecosystem services in a responsible way. This will result in sets of proxy indicators for each ecosystem service, including weighing algorithms for the quantification and assessment.

The concept of ecosystem services as a key to sustainable management of the natural resources of our planet is still in the definition stage. Showing the proof of concept, including the issues, which are part of the huge but controversial work in progress, is a further development towards practical management and policy tools. We present here a pilot study on the valuation and quantification of ecosystem services at four arable farms in the Netherlands, according to the outline above.

We combined the answers of land users of arable land in the Hoeksche Waard (S–SE of Rotterdam, the Netherlands) on questions related to their valuation of the ecosystem services with the ecological insights obtained by sampling and analyzing the ecosystems at stake. The data from the four farms were processed using the experience and the data from the nationwide soil quality network, including the Biological indicator for Soil Quality (BiSQ; Mulder et al., 2005; Rutgers et al., 2009). The assessment was done according to the principles and expressions in the Water Framework Directive (WFD; European Commission, 2000) by comparing an observed ecological state of the soil at the four farms with a state which can be considered most optimal for a managed environment, in this case arable farming on silt loam (Breure et al., 2005; Rutgers et al., 2008, 2009). In the WFD this state is called the 'maximum ecological potential' (MEP). Finally the performance of ecosystem services for each farm was discussed and related to the specific arable management system (conventional, intensive, and organic). The analysis of measures towards a more sustainable land management (step 3) for arable farming on silt loam was not a part of this demonstration.

2. Materials and methods

2.1. Choice of location for the case study

Four neighbor arable farms in a polder with marine silt loam in the Hoeksche Waard were selected (approximate position 51.725°N; 4.595°E; Fig. 2). These farms were involved in a biodiversity stimulation program (FAB: Functional Agrobiodiversity) and provided easy access to the facilities and additional data on their soil management (ELN-FAB, 2004; Van Alebeek and Clevering, 2005). The farms are indicated by capitals (Table 1): Farms A and B are conventional arable farms. Farm C is a rather large and intensive farm. Farm D is an organic farm.

2.2. Land-user consultation workshop (step 1)

Five years ago we interviewed twelve land users to describe their benefits of ecosystem services at different spatial scale (local, regional, national; Fig. 3). Land users were assigned for the sake of this demonstration only; i.e. there was no intention to use the outcome of