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Factsheet Soil and Ecosystem Services by Adrienne Grêt-Regamey, Thomas Drobnik, Lucie Greiner, Armin Keller, Andreas Papritz

Soils and their contribution to ecosystem services

Soils provide multiple services to humans. Although soils are widely recognized as valuable resource, they are rarely considered, let alone properly valued in decision-making processes. The concept of ecosystem services provides an opportunity to link soil functions and their value to human well-being. To foster understanding and finding a common language among the members of the National Research Program „Sustainable Use of Soil as a Resource" (NRP 68), this factsheet proposes a framework on how soil contributes to ecosystem services.

While the European Soil Charter of 1972 set the basis for a multi-functional understanding of soil, mono-functional approaches have overruled in the last decades: Agronomists and foresters have focused on the production function of soils and on soil fertility, soil scientists on specific soil threats, spatial planners have considered soil as a support for infrastructure and housing, water regulators have been interested in the capacity of soil to filter and regulate water, biologists have investigated the role of soil as habitat for organisms, and many international agencies have emphasized the importance of soils in natural hazard management. Nonetheless, various groups of the soil science community adopted in the past a more 'holistic' approach for assessing and valuing the many functions that soils provide. An important step towards a multi-functional understanding of soils was the definition of 'soil quality' by the Committee on Soil Quality of the Soil Science Society of America who stated in 1997 that 'soil quality is the capacity of soil to function' (Karlen et al. 1997). The draft for a European Soil Thematic Strategy (European Commission 2006), as well as the German legislation (BBodSchG 1998), and the Austrian guidelines for soil protection (ÖNORM 2013) defined in the 1990s 'soil functions' as tasks a soil fulfills. These sources, including the Swiss ordinance related to the impact on soils (VBBO 1998) and the Swiss environmental legislation (USG, 1983), explicitly listed various functions a soil fulfills, and have been followed by many studies focusing on soil functions and their assessment (e.g. Dobos al. 2006; Carré et al. 2007; Finke 2012). However, studies that developed operational methods for quantifying soil functions have remained rare, and soil functions have thus hardly ever been considered in decision-making.

This might be one of several reasons why soil preservation is still not getting the same attention as water or air protection at the local, regional, national and international level. The need to protect the soil resource is often not even mentioned in important international reports such as the UNEP report on the need for a green economy or in the report on food security by the Consultative Group on International Agricultural Research. And the Sustainable Development Goals (SDG) still give relatively little attention to soil protection. While the goal 15 "Life on Land" explicitly addresses soil in its formulation of protecting, restoring and promoting sustainable use of terrestrial ecosystems, goal 2 "Zero Hunger", goal 3 "Good health and well-being", and goal 12 "Responsible consumption and production" implicitly call for the preservation of soil resources.

The concept of ecosystem services (ES) might provide an opportunity to foster the importance of soils on the political agenda and to link the value of soils to human well-being. ES are defined as "benefits people obtain from ecosystems" (MEA 2005) or, more precisely, as "aspects of ecosystems utilized (actively or passively) to produce human well-being" (Fisher et al. 2009), spurring the recognition of the value of soil for human well-being and integrating soil in decision-making. A review of scientific publications on ES since 1980 shows an exponentially growing use of the concept (Walter et al. 2015) and applications in many disciplines (Chaudhary et al. 2015). But, while several studies have demonstrated the importance of soil for ES provision (e.g. Haygarth and Ritz 2009; Volchko et al. 2013; Robinson et al. 2014; Adhikari and Hartemink 2016, Wall et al. 2010), soils are not well represented in ES concepts (Dominati et al. 2010; Breure et al. 2012) and operational, quantitative methods to assess soil functions contributing to ES are missing (Daily et al. 1997; Wall et al. 2004; Weber 2007; Dominati et al. 2010). Therefore, the majority of ES studies uses simple proxies such as organic matter content or soil water capacity to quantify soil functions and largely ignores the efforts that have been undertaken in the applied soil science research community to quantify soil functions more adequately and comprehensively (e.g. of reviews: Wösten et al., 2001 or McBratney et al., 2002).

Adapting the cascade model by Haines-Young and Potschin (2010), an often-used general framework for ES, Figure 1 provides a common understanding of the contribution of soil towards ES in the frame of the NRP 68, compatible with the IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services) framework (Diaz et al. 2015). A distinction between soil properties, processes, and functions helps to define a cascade of steps that clarify the contribution of soil to ES. **Soil processes** (e.g. mineralization organic matter) defined as interactions among biotic and abiotic elements of an ecosystem and **soil properties** such as pH and organic matter, condition **soil functions** (Wallace, 2007). Functions**,** as used in ecology, characterize “the role the ecosystem plays in the environment” (Dominati et al., 2010), i.e. they describe how the system delivers services. Soil **services** thus depend on soil properties and processes.

By merging the categories of soil functions defined by the Soil Thematic Strategy of the Swiss Office Federal of the Environment (FOEN) and the Soil Protection Strategy (CEC, 2006), this factsheet focuses on the following six soil function categories: (1) *regulating functions* such as functions regulating water, acting as a carbon sink, filtering and binding heavy metals, contaminants, and acids, (2) *production functions* such as agricultural production, timber production, and drinking water, (3) *habitat functions* such as habitat providing for micro-organisms and plants, (4) *archive functions* such as the capacity to conserve geological and archaeological heritage, (5) *engineering functions* such as the physical and cultural environment for humans and human activities and (6) soil as *source of raw materials.* While soils managed in a sustainable manner can perform their regulating, production, and habitat functions in the long-term, engineering and resource functions are destroyed as soon as humans use soils for these services. We emphasize this distinction by classifying the latter two functions into “use functions”, and the regulating, production and habitat functions into “ecological functions”.

There are as well different classification systems for ES. Here, we consider *provisioning services*, *regulating services* and *cultural services* of the Common International Classification of Ecosystem Goods and Services (e.g. Dominati et al., 2014) and explicitly add *supporting (soil) services* as an input to the **final ecosystem goods and services (FEGS)** in order to emphasize the importance of soil for supporting the supply of ES. We also link the soil “use functions” to their services by adding the categories *engineering, archive, and resource services*. FOEN defines FEGS as goods or services that are provided by nature directly and are consumed by humans or used to produce market goods (Staub and Ott, 2011, p. 26). The term FEGS allows thus to avoid double counting of services, making a clear distinction, between services contributing to ES and services directly generating wellbeing or directly contributing to the production of a good or a service (e.g. Boyd and Banzhaf 2007, CICES 2013). Soils, on the one hand, can provide a service directly, such as for example carbon sequestration, or, on the other hand, they can contribute to ES, for example as intermediate services in terms of water filtering and/or water storage for the final service of agricultural production. Agricultural production is thus the final ecosystem service, which not only depends on the supporting (soil) services but also on suitable climatic conditions, crop choice, fertilization, pest management as well as on the socio-economic context in which production takes place.

Each FEGS can then be attributed to one or multiple **benefits** for or **threats** to humans. These benefits or threats indicate the type of contribution to well-being. We adopted the MEA (2005) classification of benefits to match the product groups defined by the FOEN (economic benefits, security, health, and biodiversity). Trade-off situations are generated, when the use of one ES directly decreases the benefits supplied by another, and synergies, in contrast, are situations where the use of one ES directly increases the benefits supplied by another service. The use choices depend on power relationships among stakeholders and on institutional and knowledge mechanisms that mediate the interactions between stakeholders and with their environment. Managing multiple ES, while taking into account these trade-offs and synergies, thus requires disentangling the underlying mechanisms of these ES interactions, e.g. identifying common supporting services, responses to common pressures, functional interactions among services. The **governance** therefore affects the ecosystems through direct or indirect drivers of changes.

Figure 1 presents a possible workflow from the contribution of soil to ES and, hence, to benefits of nature to human well-being:

- Information on soil properties or soil processes are needed to quantify soil functions in a static (assessment of potential function that a soil can fulfill independent of current land use) or dynamic manner (assessment by soil process models that takes changing land use over time into account). Digital Soil Assessment (DSA) is the process of spatial mapping results of soil function assessments.
- The different soil functions either directly contribute to the supply of a supporting (soil) service or can be combined with other ecosystem functions to contribute to ES supply. Taking ES demand into account is then necessary to assess ES.
- Various decision support tools such as cost-benefit analyses, multi-criteria decision analyses, life-cycle assessment can be used to weigh the various ES against each other to support decision-making about the benefits to be fostered or the threats to be prevented.
- Finally, feedback loops are generated through changes in land use and land management fostering some ES and impacting the provision of other ones, such as through the conversion of agricultural land to settlements, the intensification of the uses or the exploitation of the resources. These impacts can change soil properties, soil processes and functions in the short and/or in the long-term, which will again modify ES supply and ES demand. In other words, to satisfy future demand for ES, securing soil functioning by sustainable use of soil is crucial.

Conclusions

The presented framework provides a common understanding on the contribution of soil to ES within the NRP 68. Framing the value of soil in terms of ES and sustainable development goals offers new perspectives for the soil science discipline. The ES concept provides an opportunity to emphasize the contribution of soil to human well-being even more explicitly, and it allows a discussion about synergies and trade-offs of services — an important step for informed decision-making.

Suggestions for Reading

- Adhikari, K., & Hartemink, A. E. (2016). Linking soils to ecosystem services—A global review. Geoderma, 262, 101-111.
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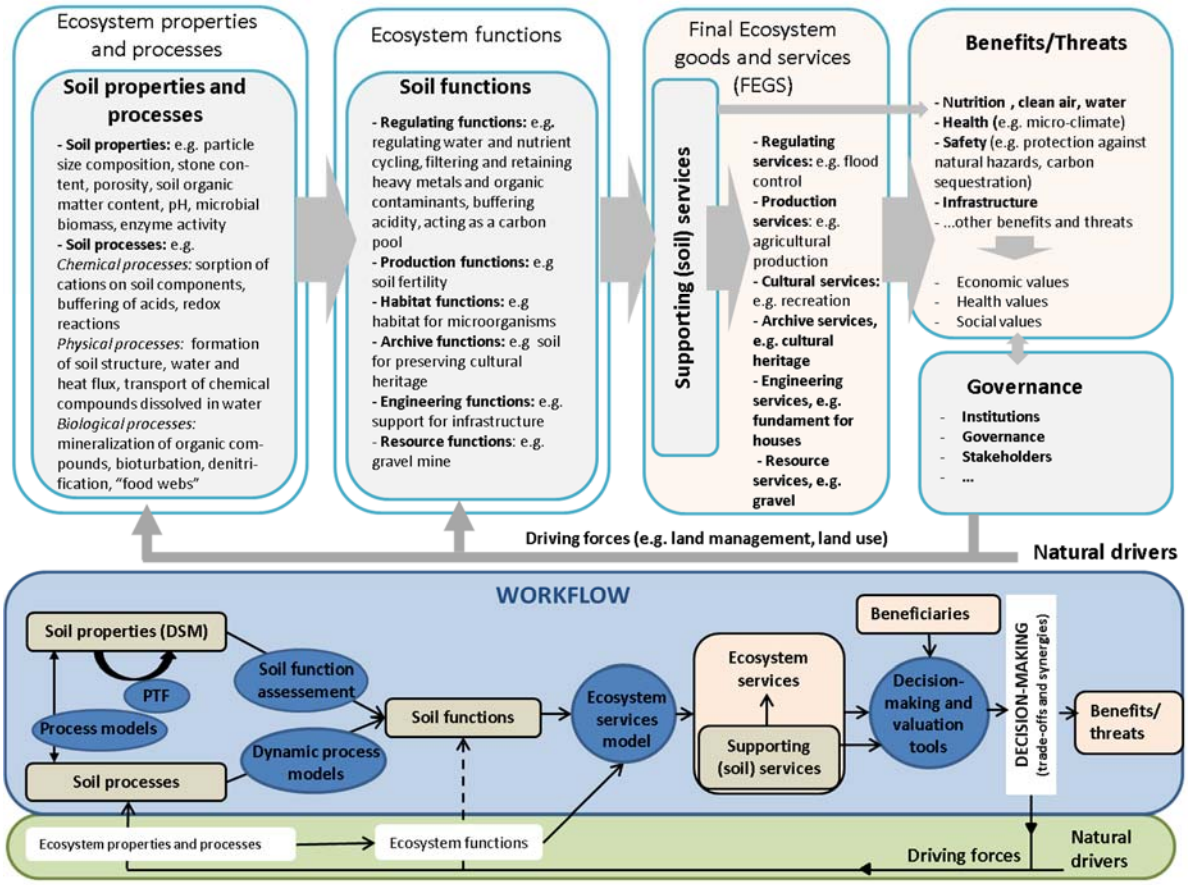

Figure 1: Framework and workflow on how soil contributes to ecosystem services

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