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Soil function evaluation in Austria — Development, concepts and examples

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ABSTRACT

Spatial planning decisions are frequently driven by short term economic interests influencing zoning regulations which determine subsequent spatial developments in the future. Not only does this frequently place constraints on prospective space for planning measures; it also leads to progressive soil loss. In order to integrate soil-related issues in decision-making processes, a broad range of specific soil services should be considered. Thus, approaches have been developed to convert available soil data to decision-relevant soil information. Soil function evaluation is used as a tool for differentiating soils due to their role in a functional context. This paper outlines development and concepts of this approach on the basis of available soil data records in Germany and Austria. It also demonstrates how an adapted hemeroby ranking can be integrated into soil evaluation. Furthermore, we present some evaluation examples from Austria, showing evaluation results and how to communicate them for better integration into spatial planning decisions. In general, this soil evaluation approach provides evidence that the results are suitable to be introduced into spatial planning procedures, which is crucial for sustainable land use in the future.

1. Introduction

In response to the progressive loss of agricultural soils in Austria due to expanding infrastructure as well as urban and rural sprawl (Umweltbundesamt, 2010), the advisory board for soil fertility and soil protection of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW, 2013) has prepared a manual on soil evaluation which has since been made into an Austrian standard (ÖNORM L 1076) by the Austrian Standards Institute (2013). Both documents should promote and standardize soil evaluation as a contribution to sustainable spatial development. In particular, the manual serves as a guide for the methodical implementation of soil function evaluation and as an instruction for consultants who get involved with soil evaluations in the course of strategic spatial planning.

In general, soil evaluation means to assess the services of soils in a specific functional context. In this broad sense soil evaluation goes far back in the history of mankind (McNeill and Winiwarter, 2006; Brevik et al., 2015). Nevertheless, scientific methods of soil evaluation were developed within the last century and progressively improved until the 1970s. However, these methods were mainly developed to assess soils related to their agricultural, horticultural and silvicultural value. In 1976, the Food and Agricultural Organisation of the United Nations (FAO, 1976) published the "Framework for Land Evaluation", extending soil evaluation to some new aspects. In Germany, Brümmer (1978) introduced the concept of multifunctionality, which considers ecological aspects such as filtration, buffering capacity, degradation and other process-oriented features. On this basis, a more holistic approach to soil function evaluation was developed and achieved wide acceptance (Karlen et al., 1997).

In the 1980s many efforts were launched to develop methods for assessing soil functionality and delivering suitable soil data in different federal states of Germany (e.g. Voerkelius et al., 1989, Benne et al., 1990). In 1995, the first soil evaluation concept was published by the state office of Baden-Württemberg in Germany, and in the following years many of the algorithms have moved to application (MfU, 1995). The year 1998 was an outstanding year in terms of a holistic soil evaluation approach, as Germany adopted the Federal Soil Protection Act (BBodSchG, 1998), which constitutes the most comprehensive soil-related law on the national level in Europe. It established a clear differentiation of soil functions and therefore strongly promoted the development of corresponding evaluation methods. Consequently, much of the fundamental literature on soil evaluation in the sense of the German Federal Soil Protection Act exists only in German. Additionally, these methods were developed to be integrated into planning procedures. As a consequence, only a few of these approaches were discussed in scientific journals. Nevertheless, some years later, Ad-hoc-AG Boden (2005a, 2005b) and LABO (2003) gave an overview and comparison of the huge number of existing soil evaluation methods. As conservation of

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soil functions has been realized as also being an urgent issue in urban areas, some prominent examples of soil evaluation projects came from German cities (e.g. Holland, 1995, Hochfeld et al., 2003, SenStadt Berlin, 2006, Tusch et al., 2007). Likewise starting from soils in urban areas, soil evaluation methods were tested and refined in the comprehensive international EU-Project TUSEC-IP, with intensive discussions between soil scientists and planners (Landeshauptstadt München, 2006, Lehmann et al., 2008, Tusch et al., 2009).

Within the European context, the year 1998 also has to be emphasized as the year in which the Protocol on the Implementation of the Alpine Convention of 1991 in the Domain of Soil Conservation (CIPRA, 1998) was signed by all statutory member states of the Alpine Convention. Similar to the Federal Soil Protection Act (BBodSchG, 1998), this document differentiates the soil functions in the following way (CIPRA, 1998):

i) Natural (ecological) functions:
1. living environment for humans, animals, plants and micro-organisms;
2. characteristic element of nature and the Alpine landscape;
3. integral part of the ecological balance (especially water, nutrients); and
4. filter, buffer and transformer of substances.

ii) Historical (socio-cultural) functions:
1. Archive of natural and cultural history.

iii) Land use (socio-economic) functions:
1. source of raw material (clay, peat, gravel);
2. location for agricultural use including pasture farming and forestry; and
3. space for human settlement, tourism recreation, transport, supply as well as water and waste disposal, etc.

In Austria, soil evaluation and subsequent activities were stimulated by this document (CIPRA, 1998), as attempts were made to implement soil evaluation in planning procedures as a contribution to sustainable spatial development. The first attempt to evaluate soils in this way started in 2005 (Geitner et al., 2005). Since then, more and more projects dealing with this issue have been performed (see Table 1). In 2013, an Austrian standard (ÖNORM L 1076) was established by the Austrian Standards Institute (2013) to emphasize soil evaluation for planning practice. This document specifies soil functions for which an assessment (soil function evaluation) is required. The relevant terms, a classification of soil functions, the general process of soil function evaluation, and the minimum requirements for the evaluation methods are specified for this.

This paper is a brief review of all Austrian attempts to evaluate soil functions, and it introduces two projects. The first example focuses on soil functions in a local context, and the second one on a state-wide scale. Both case studies used different basic soil data and lead to soil function maps. But up to now, there has been a missing link concerning how to implement this information in spatial planning. In this article, the second example presents an approach which may allow the bridging of this gap.

2. Data and concepts

Preventive soil protection is one of the objectives of the German Federal Soil Protection Act (BBodSchG, 1998), and therefore it is obligatory to introduce its issues to planning and authorization procedures (Ad-hoc-AG Boden, 2007). The first paragraph of this statute defines the purpose, which is the sustainable maintenance or the recovery of soil functions. Due to this requirement the German federal states have developed methods to evaluate the functions of soils and to consider the results within their land use planning. The evaluation methods operate with two data records for arable soils. On the one hand, the pedological field survey (bodenkundliche Landesaufnahme) is available in each federal state but differs from state to state with regard to scale and investigation objective. On the other hand, German soils are registered in the soil taxation survey (Bodenschätzung) where soil information concerning soil fertility and productivity of each parcel is incorporated.

The available soil information in Austria is quite similar (Blum et al., 1999). There are two data inventories covering the whole state's land under agricultural use, which incorporates 38% of the national territory: the agricultural soil map (Bodenkartierung) and the soil taxation survey (Bodenschätzung) (Blum et al., 1999). The agricultural soil mapping was conducted at a scale of 1:10,000 (scale of maps is 1:25,000). The sampling was performed using percussion drills of one meter length, and the frequency of sampling depended on soil diversity conditions, but averaged one drill per hectare (Schneider et al., 2001). The soil taxation survey comprises the investigation of the soil with regard to its properties and conditions, as well as the determination of the natural productivity, which is derived from bedrock, soil properties, topography, climate and water conditions (Wagner, 2001). The previous soil taxation survey was conducted at a scale of 1:2000, the sampling was done by percussion drill and its frequency followed a grid of 40–60 m cell size (Blum et al., 2003). Both data records contain soil properties like soil type, horizons (sequence and thickness), texture, C_{org}-content, content of carbonates etc.

Basically, the approaches for soil function evaluation can be divided in two groups, depending on the data base used (Ad-hoc-AG Boden, 2007):

A. On the basis of pedological soil survey

The methods evaluate the dominant and characteristic parameters as mentioned in the soil maps.

A.1. The assessments are conducted on the basis of a deduced quantitative description of the evaluation parameter (e.g. pH, C_{org}, and clay content). The methods and their iterative application are accurately defined and thus reproducible.

A.2. The assessments rely on pedological expert opinion valid only within certain regions (e.g. rarity).

B. On the basis of soil taxation survey

The soil information of this data record is not directly utilizable for evaluation. Hence, the assessment is carried out by an interpretation of the available parameters that can be done in two different ways:

B.1. Translation of soil profile descriptions into pedological nomenclature and subsequent deducing of soil functions.

B.2. Direct assessment of soil functions by interpreting a soil index (Klassenzeichen), which is one of the main results of the soil taxation survey data record, without any transformation of the raw data into a pedological nomenclature.

Usually, soil evaluation algorithms use primary parameters from maps and other data records, which describe certain soil characteristics. In a second step, these data are combined to form complex secondary data according to defined methods to assess soil performances on the basis of pedo-transfer functions. Fig. 1 exemplifies this procedure for the function “soil as a component of the water balance” (that is a sub-function of the natural soil function i 3 “integral part of the ecological balance”— see Section 1) in which one of the several assessed performances is the flow regulation using the criterion infiltration capacity for precipitation and surface run-off (GLA and LfU, 2003, Geitner and Tusch, 2008). Usually, input data as well as results are processed in GIS systems and presented as thematic maps in a spatially explicit way.

Besides the approved and frequently used basic evaluation approaches, the potential of soils as a habitat for soil organisms was