Topographic control on soil function evaluation - a case study from South Tyrol

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Abstract

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1. Introduction

Information on soil, a, at least from a human time perspective, non-renewable ressource, is of increasing importance given erosion, soil degradation and soil sealing. It is necessary to know where and where not certain practises are applicable and to adjust land-use planning appropriately. Accordingly, soil function evaluation is an invaluable tool for the future.

Haslmayr et al. (2016) and further literature

In this study, we present the soil evaluation tool *Soil Evaluation for Planning Procedures (SEPP)* and investigate topographic and parent material control of the different soil functions by applying a cross-validated machine learning approach based on availible soil pit information in the Oltradige/Überetsch region of the Autonomous Province Bolzano - South Tyrol.

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2. Data and methods

2.1. Study area and soil data

2.2. SEPP - Soil Evaluation for Planning Procedures

The software SEPP currently computes a soil function evaluation based on soil pit descriptions. It requires that the pit descriptions are performed following the Austrian Soil classification (Nestroy et al., 2000, 2011) and related mapping manuals. The minimum soil profile site characteristics are local slope, thickness of organic horizons, soil depth, groundwater table, soil parent material, soil type, humus form, altitudinal zone, moisture level and land use.For each horizon, the minimum characteristics necessary for computing the soil function are the master horizon designation, depth, pH value, proportion of the dominant soil structure type and class membership with regard to carbonate content, soil texture, organic content, abundance of rock fragments, bulk density, soil structure. These class attributes can be substituted by exact values if available. The soil functions, for which 15 different potentials are computed, are *habitat for living organisms* (specifically the potential as habitat for drought-tolerant species, moisture tolerant species, soil organisms and crops), *infiltration and drainage regulation* (minimum, average and heavy precipitation retention capacity as well as groundwater reformation rate), *natural soil fertility* as well as *filter and buffer for pollutants* (heavy metal, organic, acidifying and water-soluble). The result is a grade between 1 and 5 for each soil function potential, with 1 signifying a high potential and 5 a low one.

Potential as a habitat for drought-tolerant species. Both this potential and the following potential as a habitat for moisture-tolerant species are performed based on modifications of the approaches decribed by BayGLA and BayLfU (2003) and Lehmann et al. (2008). The evaluation of a soil's potential as a habitat for drought-tolerant species is based on the parameters land use, soil type and available field capacity. While the first two parameters are applied to distinguish especially suited (ruderal locations and corresponding soil types) or unsuited (mire deposits and soil types commonly found on these) sites, the latter is used to grade those soil profile sites showing the remaining landuse and soil type combinations.

Potential as a habitat for moisture-tolerant species. This potential is evaluated similarly to the the one for drought-tolerant species, in that specific soil types, e.g. Gleysols, are attributed specific grades. In addition, the depth of the groundwater table is used to distinguish sites with high potential, and the available field capacity is used to differentiate even further.

Habitat for soil organisms. This potential is evaluated according to Beylich et al. (2005) with some minor adaptions. In this framework, a number of species groups are used as indicators for the composition of soil life, with emphasis on earth worms (Lumbricidae) as they are influential on soil structure and bioturbation. This method is based on the relationship between soil organism communities and a number of abiotic soil parameters. Specifically, one of 14 possible soil organism communities, which are the basis for the grade awarded to a site, is attributed to a site according to a classification tree applying the parameters pH, moisture level, land use and soil texture.

Potential for agricultural production. The assessment of the potential for agricultural production is performed according to the method proposed in the framework TUSEC-IP (Lehmann et al., 2008) by an accumulative rating of five criteria. The criteria *general conditions of the profile site* is rated based on soil depth, topsoil aggregate structure and topsoil as well as subsoil bulk density. While the criteria *water supply* is based on available field capacity and the depth of the groundwater table, the grade for *air supply* is derived from air capacity and for *nutrient supply* the alkaline cation exchange capacity is regarded. The *climate* criteria is derived from the mean annual temperature of the growing season if available, or else replaced by proxy values such as mean annual temperature or altitudinal zone. The combination of the grades of the individual criteria for agricultural production leads to an overall grade that is then adjusted for the slope gradient of the location.

Average and minimum precipitation retention capacity. Following a modified versions of the procedure presented by BayGLA and BayLfU (2003), this potential is assessed by combining the permeability coefficient (using either the average value of the soil profile or the minimum value) with the water storage capacity. For more or less planar areas, the water storage capacity is regarded as the sum of the usable field capacity and the air capacity, whereas for steeper slopes only the former parameter is used. Additionally, permeability coefficient and water storage capacity is considered only for soil horizons not linked to contact with groundwater or stagnant water.

Retention capacity for heavy precipitation events. The evaluation of this soil potential is a modfied version of the scheme proposed by (Lehmann et al., 2008). It differs from the agerage precipitation retention capacity by being based on the assumption that flooding hazards are greatest when soils are already saturated with water, and therefore only the air storage capacity is considered for retention. This retention volume is then compared to the design rainfall event under consideration of the infiltration rate.

Quality of groundwater reformation. This potential is assessed using the same parameters as the precipitation capacity but considers the assumption that very quick infiltration leads to an increase of pollutants in the groundwater. In the same reasoning, soil types linked to groundwater or locations with high groundwater table are given poorer grades.

Potential for providing nutrients for plants. Adhering to (Müller and Waldeck, 2011), the assessment of this potential uses the parameter alkaline cation exchange capacity. As this is only a coarse approximation, this potential is not differentiated into five, but only three classes (poor, average and high potential).

Potential as a CO_2 sink. By applying a modified version of the rating proposed by Gerstenberg and Smettan (2005), selected land uses, especially forests, are awarded good grades, whereas other landuses are graded based on the amount of organic matter, summed up over all soil horizons.

Potential for retention of heavy metals. In this assessment , the ability to bind cadmium is used as a proxy for other heavy metals. In a first step, this ability is evaluated for different pH-values for sandy soils with little organic content, and later adjusted with regard to organic matter content and soil texture (clay content).

Potential for transforming organic contaminants.

Potential as filter and buffer for organic contaminants.

Potential for retention of water-soluble contaminants.

Potential as buffer for acidic contaminants.

3. Results

The soil function grades for each of the 15 potentials was calculated for each of the 108 soil profile pits in the study area with the SEPP app. Figure 1 shows the distribution of these grades. A first evaluation of the feature

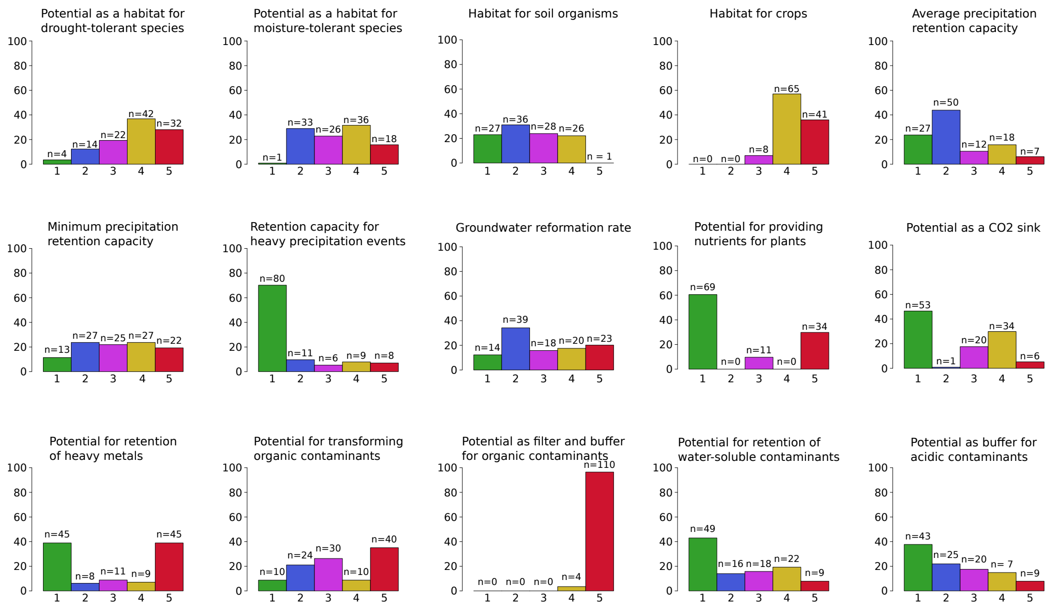

Figure 1: Barplots representing the distribution of the soil function grades for the various analysed potentials.

selection procedure shows that mostly 2 parameters are sufficient, that is that there is no increase in cross-validated prediction accuracy by adding more predictors, and most of the time these a combination of a landform classification and a local terrain parameter.

3.1. Potential as a habitat for drought-tolerant species

Figure 1 shows that of the 108 soil profile sites in the study area, 38 fall into class 4 (35%) and 32 into class 5 regarding the potential as a habitat for drought-tolerant species. The intermediate class 3 contains 21 soil profiles whereas the high potential classes 1 and 2 are attribute to only 4 and 13 sites, respectively. As the predictor set does not contain landuse nor soil type, the SVM classification essentially attempts to model the different classes of available field capacity. In the majority of the feature selection runs a landform

Table 1: Accuracy values (%) and parameters for the different potentials

potential	parameter	res	windowsize	multiacc	testacc
habitat for drought-tolerant species	landforms	10	100		
	slope	50	350	50.0	50.0
habitat for moisture-tolerant species	long. curvature	2.5	7.5		
	landforms	10	70	53.7	53.7
habitat for soil organisms	cross-sec. curvature	50	350		
	slope	50	350		
	convexity	50	150	59.3	62.0
agricultural production	slope	2.5	7.5	86.1	86.1
average precipitation retention capacity	cross-sec. curvature	2.5	47.5		
	profile curvature	10	150	50.9	54.6
minimum precipitation retention capacity	plan curvature	2.5	72.5		
	minimal curvature	50	150	41.6	46.3
retention capacity for heavy precipitation events	long. curvature	10	150	73.1	73.1
groundwater reformation rate	cross-sec. curvature	2.5	57.5		
	profile curvature	10	50	47.2	49.1
providing nutrients for plants	minimal curvature	2.5	22.5	71.3	72.2
CO_2 sink	minimal curvature	2.5	27.5	61.1	61.1
retention of heavy metals	landforms	10	70	63.9	63.9
transforming organic contaminants	landforms	10	500		
	maximal curvature	10	70	46.3	50.0
filter and buffer for organic contaminants	-	-	-	-	-
retention of water-soluble contaminants	slope	2.5	27.5		
	minimal curvature	2.5	7.5	53.7	59.3
buffer for acidic contaminants	plan curvature	2.5	12.5		
	slope	2.5	12.5	48.1	50.0

map based on a flatness threshold between 3 and 5°,a spatial resolution of 10 m and a search radius of 100 m was chosen as the first predictive feature. The landform flat is dominant amongst the profile sites with a graded potential of 5, which is accordingly connected to minimal curvature values around 0. The landform slope is most common for profiles with a potential of 4, whereas spurs and hollow can present profile locations with a potential score of 2 and, as expected, have increasingly negative minimum curvature values. A support vector classifier using theselandforms and slope at a low DTM resolution as predictor variables, results in a median cross-validated prediction accuracy of 50%, where the most common error is that a large number of sites are mistakenly classified as having grade 4. Nevertheless, the general implications of the feature selection are plausible, as flat areas can be expected to have higher field capacity values than sloping regions with negative curvature values.

3.2. Potential as a habitat for moisture-tolerant species

4. Conclusion

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