Development of soil quality indices for natural forest habitats of lowlands and uplands in Poland and its application in silviculture: project description.

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Abstract
The project involves a soil study for natural forest plant communities as a model for sustainable development of forest resources in Poland. The objective of this project is to describe the features of soils typical for specific forests types, to prepare them in a classical format and in the numerical soil quality index (SQI) and to implement this knowledge in forestry practice. Application of this index in forest site cartography is an innovation and constitutes significant progress in the research on natural soil/plants relations, which facilitates planning the plant composition for a renewed forest. The scope of work covers defining around 200 research plots within Poland's lowlands and highlands. The soil biogeochemical analyses will be held along with plant composition description and work on tree taxonomy. The research also covers the impact of individual species on soil properties, which allows description of its variability in time and space as well as its effects for SQI. The research covered by this project provides for a better use and management of forest soil resources. Sustainable forest growth as the main purpose of its management, which means integrating the production of timber, energy, clean water, carbon storage and biodiversity with the tourist and curative values of forests, is of high importance to the society. It is directed at improving the biological diversity in silviculture, as well as in farmlands designed for afforestation.

Key Words:
Pine, oak, spruce, beech, hornbeam.

Introduction
Throughout the last couple of decades, there has been a growing concern about the condition of soil quality as a measure of its capacity for performing such functions as producing plant biomass, maintaining animal health, recycling of nutrients, storing carbon, separating and distributing rainfall, buffering acidity (from anthropogenic sources), degradation and remediation of organic waste and regulating energy transformations.(Schoenholtz *et al*. 2000). Soil quality has been defined as the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen *et al*. 1997). Monitoring both agriculture and forest management requires looking at the overall quality of the soil to foresee possible changes in productivity. Productivity is a product of different factors, and in silviculture various measures of productivity have been used over the years. A site index (e.g. canopy height of a tree of a given age) is the most commonly used measure of productivity, and is influenced by factors such as climate, slope and other landscape features (geologic and topographic features), combined with soil quality. However, if the impact on productivity of various management practices in silviculture needs to be evaluated, it is more convenient to use a soil quality index (SQI). Management practices may influence the soil's chemical, physical and biological attributes, but usually they do not affect other aspects of site quality, such as the geologic and topographic features. A soil quality index is based on the assumption that there is a direct relationship between the below-ground processes (including root growth) and the aboveground productivity, and hence a particular soil attribute that restricts root growth may result in decreased aboveground productivity (Burger and Kelting 1999)

In the case of Polish forests, this standard environment management practice starts with mapping of a habitat. This work is performed for small forest areas. A proper soil survey makes the basis for a proper expertise regarding habitat and forest species composition. The classic approach to soils within habitat mapping is based on soil types, sub-types and kinds, which until now did not produce satisfying results, in particular regarding the relationship with a forest tree species composition. Soil types and subtypes are relatively large units and it is difficult to establish their clear relation to forest tree species composition. The most valuable knowledge of soil, in particular with reference to the relationship between soil and flora, is related to its properties. Laboratories provide a huge amount of data that is difficult to interpret. In the recent years there have been attempts to develop soil numerical indices that would be simple indices covering numerous properties (Andrews 2003, Huber 2005, Schoenholtz *et al*. 2000).

The first objective of this project is to specify the soil characteristics typical of forests of various composition, presenting them in the classical format and as a relatively robust, numerical quality index, and then implementing this knowledge in forestry practice. The second objective is to recognize the potential changes in soil quality indices caused by changes in forest species composition.

Methods

One part of this project is focused on finding the relationship between soil quality indices and natural forest plant communities. The work includes plant composition description, tree measurements (height, breast diameter, increment, age), soil profile characteristic and sampling. The laboratory work includes an analysis of 1,200 samples taken to cover the texture, bulk density, total nitrogen (N) and organic carbon (C) contents, soil pH in H_2O and in 1M KCl, exchangeable acidity (TE), total acidity (TA) and exchangeable Ca^{2+}, K^+, Mg^{2+} and Na^+.

The other part of the project deals with the influence of forest species on the values of soil quality indices. Research is carried out on 12 plots. For this purpose, the following pairs of plots were selected: Pine/Oak (3 pairs), Pine/Beech, Pine/Hornbeam, Pine/Spruce. The paired plots are relatively close to each other and stand on the same soil type. The plots are 20m x 20m in size. During field work, the plots were mapped (ground surface variability, location of stems and tree crown range). Soil sampling is performed on a 1x1m grid (441 per plot), samples are taken from the top 10cm, mineral-only layer of soil. These samples are being analyzed for pH in 0,01 M $CaCl_2$ solution, and for moisture content. Additionally, 16 samples from each plot are taken on a 4x4 m grid and analyzed for: pH, base cations content, total and exchangeable acidity, aluminium extracted in 1 M KCI and 0,5 M $CuCl_2$, total C and N. On some of tested plots a set of lysimeters are installed for soil solutions sampling at the depth of about 10 and 20cm. Soil solution analysis includes the following factors: pH, H^+, Ca^{2+}, Mg^{2+}, K^+, Na^+, Al (total and $Al^{(3-n)}$), $Fe^{2+,3+}$, Cl^-, SO_4^{2-}, NH_4^+, NO_3^- contents.

Preliminary results

On the basis of previous research (Brożek *et al.* 2006) and statistical analysis of the data (Brożek 2007), four groups of soil properties were selected as indicators for calculating the soil quality index. The selected indicators, calculated for 1x1x1.5m soil volume, comprised:

- the content of the <20 µm (fine) fraction of the (FF sum),
- the content of base cations (BC sum),
- soil acidity per weight unit of the <20 µm fraction (TA/FF),
- N^2 to C ratio in the top soil (N^2/C) – this parameter calculated only for the A horizons.

The next step was categorization. Each of the four indicators is subdivided into 10 classes (1 to 10) (Table 1). The highest value (10) is best for the soil quality.

Table 1. Categories of the chosen soil indicators.

class	FF sum (kg)	BC sum (kg)	TA/FF ($cmol_+$/kg)	N^2/C (%)
	range	range	range	range
1	<20	<2.3	>1.50	<0.002
2	20-45	2.4-3.6	1.50-1.11	0.0021-0.003
3	46-55	3.7-5.0	1.10-1.01	0.0031-0.0036
4	56-75	5.1-7.5	1.00-0.81	0.0037-0.0050
5	76-100	7.6-9.5	0.80-0.61	0.0051-0.0065
6	101-120	9.6-13.0	0.60-0.51	0.0066-0.0080
7	121-250	13.1-25.0	0.50-0.36	0.0081-0.0100
8	251-500	25.1-50.0	0.35-0.21	0.0101-0.0150
9	501-950	50.1-350	0.20-0.10	0.01501-0.020
10	>950	>350	<0.10	>0.02

First of all, this project is designed to choose the soil indicators that distingushing natural plant communities and to continiue the work on the classess and SQI formula.

At present, the investigations are being carried out, all fieldwork have been performed. Sampling on trial plots are also finished, and the results of the laboratory analysis are soon expected. In order to obtain the preliminary information on the impact of forest species composition on the investigated soil quality indices, we used data from the soils of homogeneous spruce forest and mixed forest predominated by European beech. Some of soil properties (e.g. texture) are dependent primarily on the parent material and considered stable, whereas others could be affected by forest type. However, both these indices and the soil quality index were developed for lowlands, and we tested their applicability to mountain forest soils.
Not surprisingly, the content of the <20 µm fraction proved to be the most stable parameter, while the content of base cations proved to be the most affected (Table 2). The magnitude of shift in the values of the soil quality index between the spruce and mixed forest was also related to the type of parent material and was most pronounced in the richest soils.

Table 2. Parameters of the soil quality index calculated for soils under spruce stands and mixed stands (average values).

Type of forest	number of profiles	Sum in profile up to 150 cm			In the A horizon
		FF sum	BC sum	TA/FF	N^2C
Spruce	36	894	28	0.362	0.018
Mixed	18	910	45	0.328	0.021
Relative change [%]		+2	+38	-10	+17

Conclusions for the project

The planned final outcome of this project is determination of the soil quality indices which will be used in habitats mapping and in planning the species composition within forest management. The developed SQI is intended to be robust and resistant to the possible influence of forest species composition. Additionally, it should be simple enough to be used in forest service as a tool for forest management promoting biodiversity and afforestation of farmlands.

Our conclusions are that the extant soil quality index is relatively stable and practically uninfluenced by forest vegetation. The only parameter strongly affected was that based on the sum of base cations. Additionally, the tests performed demonstrate that the index can also be successfully applied to mountain soils. Another important question to answer is the small-scale spatial variability of soil quality parameters. How strongly can a singular tree affect it? How many sampling points are required to cover the local soil properties variability with only an acceptable statistical error?

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