Soil Biodiversity and Nutrient Turnover in Different Forest Types of Central Europe

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Introduction

Natural old-growth forests are expected to be high in biodiversity, because the structural richness of the habitat sustains complex relationships between fauna, flora, and microflora. Our hypothesis was that forest type characteristics affect the soil biota and provoke specific nutrient turnover rates. In cooperation between field ecologists, taxonomists, molecular ecologists and biochemists we attempted to link biodiversity and biogeochemistry and gain new insights into the functioning of forest soils (DIANA homepage http://bfw.ac.at/300/2197.html).

Material and Methods

Twelve old-growth forest stands were selected which were situated within the eastern part of Austria, featuring oak-hornbeam, woodruff-beech, acidic beech, spruce-fir-beech, floodplain and Austrian pine forests. All stands were characterized by a natural tree species composition. An overview of the site characteristics and the geographical locations as well as the sampling design is given in Hackl et al. (2000) and Hackl et al. (2004a). The biodiversity of different groups of micro- meso- and macrofauna (Fig. 1) was assessed by the respective specialists after soil sampling or trapping during two vegetation periods. Here we present only data on species richness; abundance data and ecological traits are included in the database.

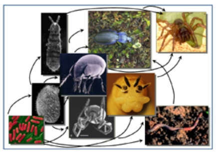

Fig. 1: Investigated soil taxa and their complex relationships (from left to right: bacteria, protozoa, springtails, oribatid mites, gamasid mites, ground beetles, diptera larvae, earthworms, spiders)

Microbial communities were analyzed by phospholipid fatty acid (PLFA) extraction and analysis, which was done as described by Frostegård et al. (1996). Delta ^{15}N natural abundance of total soil nitrogen was determined after dry combustion by isotope ratio mass spectrometry (Delta Plus, Finnigan MAT) according to Wanek and Arndt(2002).

Results and Discussion

Biodiversity

The biodiversity of all taxa was generally large in the investigated natural forest soils (Fig. 2). However, it was not larger as compared to managed forests (Fig. 3). According to the "intermediate disturbance hypothesis" assemblages of late successional stages have less species than those of intermediate stages. We suggest, that the DIANA forests might be considered such late successional stages.

Highest species richness of several taxa, such as protozoa, diptera, coleoptera, bacteria (Fig. 4) and earthworms was found in the nutrient rich floodplain forests (Waitzbauer and Wurth, 2005). The communities of microbes, protozoa, oribatid and gamasid mites as well as collembolans in these forests were distinct from those at the other sites. As compared to the other sites, rank abundance plots for these forests were linear, indicating lower site maturity (Čoja and Bruckner, in preparation). We attribute the high species richness of the floodplain forests to an intermediate disturbance regime. This is brought about by occasional flooding, which may also contribute to the higher abundance of ubiquitous species as compared to forest specialists (Fig. 5). The less fertile beech forests on acidic bedrock showed a large abundance of fungi (Fig. 4) and high biodiversity and abundance of microarthropods, such as gamasid mites and collembola. The pine forests under study were rich in actinomycetes and fungi (Fig. 4), which are more efficient in utilizing recalcitrant pine needles than bacteria. Thirteen new species of protozoa were found in the pine forests (Foissner et al, 2005). Two forest sites which were affected by high nitrogen deposition had a constricted biodiversity of all taxa and contained little microbial biomass (Hackl, 2004a). In addition, these sites were heavily disturbed by digging of wild boars (Fig. 6). Most communities of the soil biota showed clustering according to forest type. There was no direct relationship between the species richness of higher plants and the soil organisms studied.

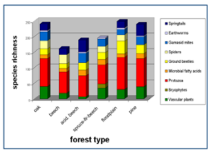

Fig. 2: Biodiversity of investigated forest types.

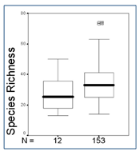

Fig. 3: Figure: Comparison of species richness between natural old-growth forests (left) and managed Central European forests of the same forest types (right) shows significant differences (Mann-Whitney U-test, P = 0.04), i.e. significant less spiders in DIANA forests.

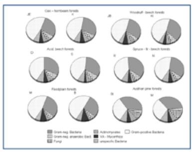

Fig. 4: Distribution of functional groups of soil microorganisms.

Nutrient Turnover

Nitrogen turnover rates were largest in the spruce-fir-beech forest soil and lowest in the acid. beech forest soil (Zechmeister-Boltenstern et al., 2005). In spite of the high turnover rates the nitrogen cycle was almost closed in the spruce-fir-beech stand. Highest loss of N occurred in the floodplain forest as nitrate leaching (Hackl, 2004a). The $\delta^{15}N$ graph (Fig. 7) shows highest ^{15}N enrichment in the floodplain forests and ^{15}N depletion in the acid. beech forest soil. Microbes tend to process the lighter ^{14}N, which can be leached after conversion to nitrate, leaving ^{15}N enriched material in microbially active soil. Low $\delta^{15}N$, as observed in the acid beech forest, indicates the presence of undecomposed plant material (Högberg, 1997).

Fig. 5: Floodplain forest show high biodiversity of ubiquitous species due to intermediate disturbance by flooding.

Fig. 6: A beech forest close to Vienna with low soil biodiversity, affected by high nitrogen deposition and disturbance by wild boars.

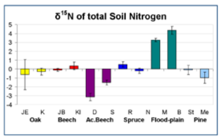

Fig. 7: N-isotopes show that floodplain forests loose more nitrogen.

Conclusions

- Diversity of soil biota in old-growth forests is large, many new species can be found.
- Moderate disturbance (such as flooding and sustainable forest management) may promote species richness but it may change community composition and eliminate rare and specialised forest species. Nitrogen leaching losses may occur.
- Severe disturbance (such as anthropogenic nitrogen inputs and high wild boar density) may negatively affect species richness of the soil biota.
- Nutrient turnover rates are related to physiological groups of the soil community and to forest type. The DIANA database (Fig. 8) has been created to find specific relationships between individual soil taxa and nutrient turnover.

Database

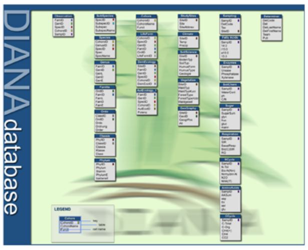

Fig. 8: Structure of database containing information on soil organisms, nutrient turnover and greenhouse gas emissions

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DIANA HOMEPAGE: http://bfw.ac.at/300/2197.html

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