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Changing microbial ecology with changing management (Workpackage 9.0)

Introduction

Soils in the Arctic and sub-Arctic regions show low nutrient contents. They further face harsh environmental conditions by low temperatures and low precipitation. This holds true for soils in the open tundra regions as well as for northern forests. Further, short vegetation periods limit the production and even stronger the decomposition of organic material, which has led to accumulations of organic matter in several regions. Wide spread moraine deposits on Scandinavian fjells show high contents of sandy material. Such soils are easily leached by melt water or rain water. Pine forests show mainly nutrient-poor soils due to elevated acidity followed by podzolization.

Such environments are regarded to be strongly susceptible to changes by global warming, changes in precipitation, and changes in land use. The latter ones are caused by intensifications of forestry, industry, tourism or agriculture. As such, changes in reindeer herding can have severe effects on soils, e.g., soil cover, soil stability, soil chemistry and biology. Soils with only thin covers of organic material may act quickly and in way to a new, even poorer state. Hence, limited grazing grounds due to increasing competition with other demands lead to changes in pastures with consequences on the soil environments and soil biology.

Soil quality results from various factors, e.g., litter quality, soil structure, soil organisms and others. Processes responsible for nutrient recycling, degradation and turnover of organic matter are mainly carried out by soil microbes. In turn, they depend on organic and inorganic nutrients, moisture and other environmental variables.

It was the primary task of this workpackage to study and describe the microbial communities and their activity in different soils. They were under various management regimes and thus had very different constraints to microbial processes. In order to relate those microbial characters a close cooperation with other disciplines was necessary. A common data base of soil properties is a main result of this Workpackage, which serves as basis for descriptions in a changing environment.

Material and methods

There are different aspects, which need to be considered during such studies on environmental aspects, which are suspected to be due to men's influence. On the one hand it is necessary to find non-contaminated or non-disturbed sites, on the other hand there are several degrees of disturbance possible, which are not always very clear in the field. Thus, it was necessary to look carefully for those sites, which might fulfil our demands to describe actual state related to changes in herding. Further, we had two different locations for our study, the forest environment near Vuotso and the fjell area north of Näkkälä.

The latter one was a site where two different management regimes were next to each other, separated by the border fence between Norway and Finland. The most obvious distinction between these regimes is the local vegetation, *i.e.*, the cover of lichens, which is denser in the Norwegian landscape. For reasons of clear distinctions between such management systems, we decided to have this area as a test for our study on soils and soil microbiology especial with regard to soil cover and soil degradation. A grid of sampling sites was put into this area in order to have a clear set of data from both sites.

The forest region near Vuotso served as a site, where we mainly put emphasis on differences in forest soils and those of corrals, *i.e.*, heavily influenced sites by strong trampling. Further, we put emphasis on faecal indicators by investigating soil samples, which were in direct contact with faecal pellets. These samplings were performed in corrals and along roads.

However, these regions can only partly be regarded as "typical" for Northern Scandinavia and we have to restrict our results – and interpretations – to those locations (=environments) under evaluation. This was our task within the RENMAN project. Nevertheless, the two districts (Paliskuntas Näkkälä and Vuotso) might serve as a model for a greater, similar region, but extrapolations to other locations bear the difficulty of misinterpretations by "overestimations" of current data. It has to be born in mind that our environmental descriptions should serve for a better understanding of the actual state of environmental properties.

Direct comparisons with data from other studies render difficult, although it is obvious that they will be taken into consideration during the discussion of our data. Monographs with similar tasks have been performed and published recently by Kumpula (2001), Stark (2002), Eilertsen (2002), and den Herder (2003). Those studies and other publications will be considered and further discussions will be performed in our final publications on this matter. This paper is just dedicated to present preliminary results.

Methodologies

The analysis of natural microbial communities was performed by epifluorescence microscopy. Detailed descriptions of this method are presented elsewhere

(Bölter et al. 1993, Bölter et al. 2002). All samples were analysed for their respiratory activity by infra-red gas analysis in order to get a figure of the soil microbial activity. These analyses were performed at different temperature steps (5°C - 40°C). In addition to the epifluorescence studies, we analysed several samples from faeces and soils by gene probes for different human-pathogenic strains. Further, samples from the transect across the border between Norway and Finland (Näkkälä 2002) were analysed for DNA contents in order to get another data set for microbial biomass. An overall estimation of soil organic matter was performed by measuring the LOI (% loss on ignition at 520 °C of dry weight). Soil respiration measurements were performed by incubation in chambers with continuous measure of CO_2 in the flowing gas (Sommerkorn et al. 1999, Bölter et al. 2003).

Results

The microscopical inspections show a commonly known distribution in the soil profiles. The samples from Vuotso taken in 2001 showed for surface layers (0-4 cm) a content of organic matter (LOI) of about 10.6% (median value), the layer 4-20 cm showed a median of 3.3%, those of depths >20cm had contents of only 1.1%. In relation to this, bacterial numbers per gram dry weight (medians) can be found at 4.4×10^8 (0-4 cm), 1.7×10^8 (4-20 cm), and 6.2×10^7 (>20 cm). A decrease in mean cell volume (medians, μm^3) with depth (2.6×10^{-2}; 2.0×10^{-2}, 9.6×10^{-3}, resp.) leads to even stronger decreases in bacterial biomass. CO_2-evolution (µg CO_2 per hour and g soil) of samples taken in 2002 showed a concomitant decrease with depth (at 20 °C) (2.5, 1.5, and 0.4 µg CO_2 g^{-1} h^{-1}, resp.). Derived Q_{10}-values show medians around 2 (range: 1.1 – 2.7).

The microbial community is dominated by bacteria, an effect which is probably due to the dry condition during the sampling time in summer. Thus, soil algae are rare, photosynthetic organisms are mainly restricted to small cyanobacteria. Fungi (filamentous and yeasts) also do not have a significant share on microbial biomass.

Direct effects of faeces are only locally relevant and in direct relation to droppings. The analysis by RNA probes for coliforms and *E. coli* have shown positive results in faeces but in soils only to a much lower extent. The first assumption that those large cells (length > 3µm), which could be monitored in many samples by epifluorescence microscopy, belong to coliform bacteria could not or only partly be verified. Positive results for those tests were found only in faeces, but not in soil samples. However, it is noteworthy that positive results could be even verified for samples, which were stored for several months in the freezer. This means that potential pathogenic bacteria like *E. coli* have a long time for survival. Their morphology also did not change significantly from those of fresh samples.

For soil microbiological studies in 2002, focus was laid on analyses of soils from the Jauristunturit Region for soil organic matter, soil microbial communities, and soil respiration. Surface samples (0-4 cm) from soils were taken during the field season in summer 2002 where 6 transects were laid across the border fence between Norway and Finland.

The results of the analyses showed only weak or no differentiation between the areas of Norway and Finland, despite differences in soil covers. The Norwegian

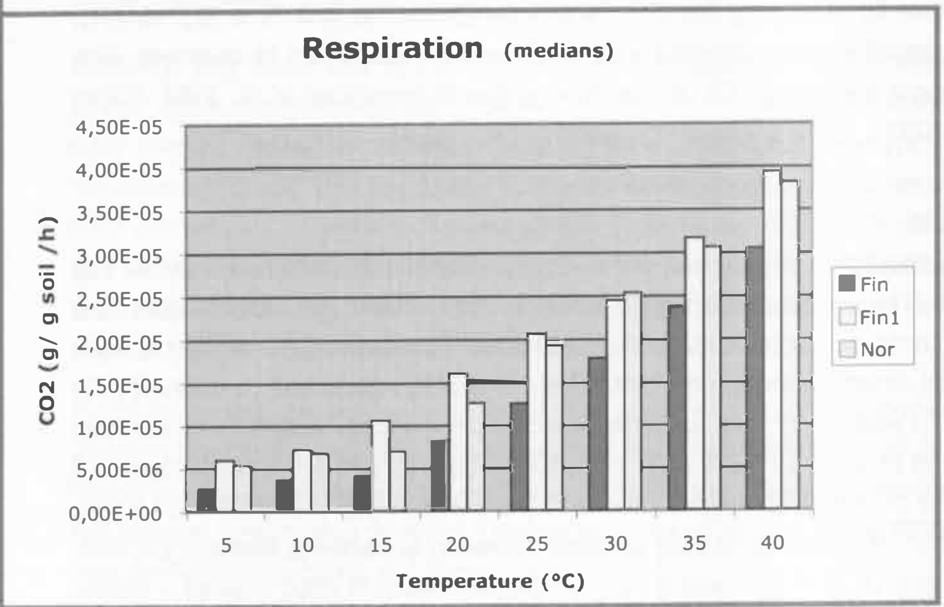

Figure 1 *Soil respiration (median values) for the sites in Finland (Fin, Fin1) and Norway (Nor).*

sites had much more lichens than those of Finland, where higher plants dominated the vegetation. The distribution of soil organic matter is strongly related to soil cover in general and does not show clear tendencies when comparing the parts north and south the fence. Microorganisms are closely related to the contents of the soil organic matter. Significant separations between the sites north

Table 1 *Minimal and maximal values (min, max), and medians for soil microbial descriptors of fjell samples in the Jauristunturit region north (Norway) and south (Finland) of the fence.*

Item	Norway (n=42)			Finland (n=43)		
	min	median	max	min	median	max
LOI (% of dry weight)	14.3	48.3	89.1	5.1	48.2	80.9
CO_2-evolution at 20°C (µg CO_2 / g soil x h)	3.43	14.8	50.7	2.16	10.5	72.2
Mean cell volume (10^{-2} µm^3)	1.15	1.76	3.0	0.92	1.82	2.8
Total count (n x 10^8 / g soil)	1.02	4.99	19.0	1.29	3.95	13.7
Bacterial biomass (µg / g soil	1.36	10.4	49.9	1.56	8.37	22.7

and south the fence are not possible by the parameters for bacteria (counts, biovolume, and community structure), an overview is given in Table 1.

The microbial communities of these transects are dominated by bacteria. Soil algae and fungi are present but rare. There is no significant evidence for wide spread pollution indicators (*e.g.*, coliform bacteria). Faecal indicators are restricted to places where direct contacts of soils with faeces are present. Soil respiration is not directly influenced by the different land use in Finland and Norway on the scale of our investigation field. Correlations between bulk organic matter and microbial activity (soil respiration) are not significant; soil respiration is more closely related to environmental parameters (temperature and moisture). Lowered respiration data can be seen locally where trampling has destroyed the plant cover and degradation of the organic layer has occurred, which is more frequently observed at Finnish sites.

These data of surface samples go along with other data from surface samples from Vuotso and Näkkälä, which were taken at places with faecal pellets. No direct influences of those pellets could be monitored by the parameters analysed for most samples. The few results, which could give a hint for faecal pollution of soils were rare and did not show any evidence for an increased risk by contaminants. Further, those few enlarged organisms, which were found during the microscopic inspections, obviously do not influence the total population.

Discussion

This WP was designed to describe changes in the microbial environment, the microbial communities and their effects on nutrient cycling in relation to different land-use scenarios. Main efforts were be put on the collections of data on various parameters in order to provide significant information of the soil habitats and possible effects to the environment. Results will be linked especially to those of soil-physical (WP9.1) soil-chemical (WP10) and soil-hygienic (WP9.2) studies carried out at the same profiles to obtain a more complete picture of the effect of reindeer grazing on soil properties.

The analyses of the microbial communities of the soil samples have revealed the result that potential pathogens have long survival times even under frozen conditions. The share of those organisms in the total community can be significant in freshly contaminated samples, such effects, however, are obviously locally restricted. The situation of a low load of enteric bacteria may become totally different, if additional fodder is consumed. Related studies have been performed by WP9.2.

During our studies in the Jauristunturit region, no direct effects on the soil microbial organisms became evident. Microbial communities and microbial activity, *i.e.*, abundances of organisms and their potential to recycle nutrients, are less influenced by the land use patterns in this region. Effects of grazing on soil biological processes become noticeable when the soil cover (plant cover, litter, humics etc) is strongly degraded. But such places are rare and effects can only be seen on intensively used localities, *e.g.*, corrals, trampling paths close to the fence, or vehicle tracks. Critical effects are due to environmental constraints, such as changes in soil moisture and temperature. Although such constraints may change due to increased herding, the actual management does not show significant impacts on soil microbial communities and activity.

The ranges of microbial biomass, soil respiration and other data are well comparable to other tundra environments in the northern regions. However, extrapolations to other landscapes (*e.g.*, wet lands, forests) cannot be drawn without precise knowledge on the specific local conditions.

The soils of the tundra and forest environment do not show a state of heavy pollution due to animals - except at places of dense population like in temporally used corrals. These contaminations are not significant for long term changes in general activity parameters like CO_2-evolution. However, care has to be taken to places of dense herds or where high amounts of pollutants can accumulate. In such places, there is a risk for spread of deseases due to the long survival of enteric bacteria in soils with high loads of organic matter (Bölter & Höller 1996, Bölter 1996).

It could further be shown that the extent of grazing as performed actually does not alter significantly the soil microbial flora. Impacts of trampling and heavy grazing can be shown only next to the fences, where trampling and "roads" show effects on soil cover, amount of soil organic matter, and litter. Due to such effects, erosion and desertification become more important.

Conclusions

The results of these analyses show for most soils the "normal" distribution of organisms in northern habitats. Total number and biovolume of microbes are in ranges of tundra sites in Siberia or Canada (Bölter & Kanda 1997, Bölter 1998, 1999, 2001, Schmidt & Bölter 2002). The individual data for parameters of the bacterial community for surface soils without faecal droppings do not show exceptions, which might be used to describe a special situation for an increased health risk. Only few soil samples in close vicinity or just beneath faecal droppings (samples from the forest at Vuotso), however, show an increase in number of large bacteria, which can be compared to reference cultures of *Escherichia coli* and *Clostridium perfringens*. However, RNA-probes did not show positive reactions.

Similar to the results of the microbial community analysis, for most samples the soil respiration data do not show exceptions from the normally occurring

CO_2-evolution data from tundra environments (Sommerkorn et al. 1999, Bölter et. al. 2003). This fact indicates that neither the (active) microbial community nor its nutrient supply show exceptions. Noticeable effects can be seen in the temperature curves of the Näkkälä-samples. Here, an increase in respiration activity can be monitored at temperatures above 25 °C. Hence, the above mentioned populations of enlarged cells or any other special microbial population probably do contribute significantly to the turnover of the available organic matter.

Secondary effects, like erosion of soils on degraded sites where the plant cover is disturbed by animals (increased grazing) or men (traffic paths, corrals, clear cuts, ski loipes and skidoo paths), need further consideration and may become of greater influence to the environment in the near future than actual herding.

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