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Content

Early system genesis following large scale mining disturbances

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Introduction

Surface mining, considered to be one of the most destructive anthropogenic disturbances (Schaaf and Hüttl 2005), is a common practice in many countries worldwide. Regardless of the resource being mined, the course of action is roughly the same: vast amounts of extraneous spoil or overburden material are excavated, stored and eventually returned to fill the pit, or if insufficient material is available, end pit lakes are formed by allowing water to seep back into the pit. Following mining and backfilling, the ecosystem that was destroyed to access the resource must be recreated, including the re-establishment of deep and shallow hydrologic flows, biogeochemical cycling and ecosystem functions (Johnson and Miyanishi 2008).

One of the most obvious priorities following mining is the re-establishment of vegetation, from both management (erosion prevention) and ecological (ecosystem genesis) perspectives. There is a wealth of literature on plant community development via primary and secondary succession, with a distinct portion examining establishment of plant communities following large scale mining disturbances. These studies often assess the driving forces in spontaneous plant community development through primary succession at barren mine sites. For example, Weigleb and Felinks (2001) studied the relationship between environmental parameters and development of plant communities in the Lusatian brown coal mining district on 5 to 70 year old sites to determine predictability of early stage of primary succession. They found that environmental parameters and age could not completely account for the variance and that spatial aspects and the nature of reclamation measures should be included in the analysis. A study by Craw et al. (2007) found that plant community development on waste rock piles in New Zealand was determined by physical properties of the substrate, with cohesion, water content and proportion of quartz pebbles being important factors.

This research will examine similar soil-plant interactions but unlike the previously mentioned studies, active reclamation measures were undertaken and a native propagule source was applied at the study sites. The native propagule source consists of salvaged litter layers (LFH) and upper soil horizons from an upland boreal forest and is referred to as forest floor - mineral mix. It is hypothesized that propagule distribution in the seedbank will significantly affect vegetation distribution during early development stages, but the role of soil properties and site conditions and the effect of age under these conditions is not known and will be investigated. This project will integrate research by Mackenzie (2006) and Brown (2010), whose work with Dr Naeth focused on plant community establishment on forest floor - mineral mix. My research is expanding the scope of their individual projects.

The study will take place in the Alberta oil sands where an estimated 602 km^2 (0.16% of Alberta's boreal forest) have been disturbed by oil sands mining, with the potential for considerably more disturbance in the future (Government of Alberta 2009). Oil sands extraction is one of the major disturbances in Alberta, and provides 99% of Alberta's proven oil reserves, which together account for 13% of global oil reserves (Government of Alberta, Department of Energy 2010a). An estimated 170.4 billion barrels of recoverable resources are in the oil sands region, which underlies 142,200 km^2 in

northern and eastern Alberta (Fig. 1) (Government of Alberta 2009, 2010). Of this, 20% of deposits are within 75 m of the surface and are therefore recoverable by surface mining. The remaining 80% can be extracted using in situ methods such as steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS), where wells and pipelines similar to those used for drilling for conventional oil are installed (Government of Alberta, Department of Energy 2010b).

Figure 1. The oil sands region of Alberta, Canada (Government of Alberta 2009).

A meta-analysis using data from my field study, from oil sands sites reclaimed using different practices and from research sites in Germany's brown coal mining sector will be conducted. Open pit brown coal (lignite) mining in Germany occurs on a scale similar (or greater) to that of the Alberta oil sands, and reclamation efforts are analogous in that entire landscapes must be rebuilt. There are several lignite mining areas in Germany, although the focus here will be on the lower Lusatia mining district located in the southern Brandenburg and northeastern Sachsen, 130 km southeast of Berlin and 100 km north of Dresden (Weigleb and Felinks 2001), where more than 780 km^2 are affected by lignite mining (Schaaf and Hüttl 2005).

Objectives

The main objective of this research is to examine early ecosystem genesis and the key processes associated with it in areas that have been disturbed by large scale mining operations. The focus is on plant-soil interactions, specifically investigating the natural and anthropogenic drivers in plant community development and succession at an early stage. The main research question will address the trajectories that plant communities follow as a result of similar or different starting points and what main factors (functions and processes) affect these trajectories. Specific objectives are as follows.

- To examine development of plant communities on forest floor - mineral mix reclamation treatments by assessing plant species composition, richness and diversity, native and non-native species (plant origin groups), morphological groups and groups of species with particular strategies.

- To examine the development of soils on forest floor - mineral mix reclamation treatments by assessing soil physical, chemical and biological properties.
- To examine spatial and temporal relationships among soil properties and the plant community.

Experimental Design

The field portion of the project will take place at four previously established sites in the Athabasca oil sands north of Fort McMurray (Figure 1). The sites vary in age from two and a half to seven years. The experimental design of each site is a randomized block with a number of replicated treatments. Of these, only the forest floor - mineral mix treatments will be studied in the field study. The forest floor - mineral mix was obtained by salvaging a mixture of LFH and the uppermost horizons of the underlying soil from nearby sites to a depth of 20 cm. It was applied at all of the sites as a plant growth medium and source of plant propagules. At three of the four sites, two different application depths were used (10 and 20 cm), and a 20 cm depth was used at the fourth site. The texture of the underlying horizon to which the forest floor - mineral mix was applied differs among sites, ranging from clay loam to sand. The forest - floor mineral mix donor sites had different types of vegetation such as Populus tremuloides Michx. forest, Pinus banksiana Lamb. forest or mixedwood forests, which change the species present in the seed bank of the salvaged LFH. Comparisons will be made among different application depths, substrate textures and LFH types for each different age with available data.

Materials and Methods

Several vegetation parameters will be measured using quadrats along transects to assess development of the plant community including canopy cover and biovolume by species, ground cover and density of woody plants. The species will be categorized into groups based on their life history strategy, origin, morphology, successional stage and C-S-R functional type (Hodgson et al. 1999, Hunt et al. 2004) to examine community dynamics.

Soil chemical and physical properties to be measured are pH, electrical conductivity, organic matter, carbon to nitrogen ratio, available nitrogen and phosphorus, potassium cations, texture, volumetric water content, penetration resistance and temperature. The soil microbial community will be evaluated by quantifying microbial biomass carbon using the method by Vance et al. (1987) and mycorrhizal biomass using glucosamine assays (Nilsson and Bjurman 1998, Appuhn et al. 2004, Appuhn and Joergensen 2006). Site conditions such as aspect, slope and slope position will be included in the analysis.

Results

Results from the first field season of this research analyzed in conjunction with results from previous research conducted on the research sites will be presented at the conference.

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Visualization of soil structure modifications by pioneering ground beetles

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Abstract

An artificial catchment was constructed to study initial soil and ecosystem development. As a key process, the pore structure dynamics in the soil at the surface strongly influences erosion, infiltration, matter dynamics, and vegetation establishment. Little is known, however, about the first macropore formation in the very early stage. This presentation focuses on observations of soil pore geometry and its effect on water flow at the surface comparing samples from three sites in the catchment and in an adjacent “younger” site composed of comparable sediments.

The surface soil was sampled in cylindrical plastic rings (10 cm³) down to 2 cm depth in three replicates each site and six where caves from pioneering ground-dwelling beetles Cicindelidae were found. The samples were scanned with micro-X-ray computed tomography (at UFZ-Halle, Germany) with a resolution of 0.084 mm. The infiltration dynamics were visualized with neutron radiography (at Paul-Scherer-Institute, Switzerland) on slab-type soil samples in 2D.

The micro-tomographies exhibit formation of surface sealing whose thickness and intensity vary with silt and clay content. The CT images show several coarser- and finer-textured micro-layers at the sample surfaces that were formed as a consequence of repeated washing in of finer particles in underlying coarser sediment. In micro-depressions, the uppermost layers consist of sorted fine sand and silt due to wind erosion. Similar as for desert pavements, a vesicular pore structure developed in these sediments on top, but also scattered in fine sand- and silt-enriched micro-layers. The ground-dwelling activity of Cicindelidae beetles greatly modifies the soil structure through forming caves in the first centimetres of the soil. Older collapsed caves, which form isolated pores within mixed zones, were also found. The infiltration rates were severely affected both, by surface crusts and activity of ground-dwelling beetles.

The observations demonstrate relatively high abiotic and biotic dynamics of soil pore structure in the soil surface even during the very early development stages. The structure formation has potentially great effects on changing runoff and infiltration by forming sealing layers or preferential flow paths.

Observations of flow path interactions with surface structures during initial soil development stage using irrigation experiments

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Abstract

Structures and processes are dynamically linked especially during initial stages of soil and ecosystem development. Here we assume that soil pore structures and micro topography determine the flow paths and water fluxes as well as further structure changes. Reports about flow path developments at the soil surface are still limited because of an insufficient knowledge of the changing micro topography at the surface.

The objective of this presentation is to evaluate methods for parameterisation of surface micro topography for analysing interactions between infiltration and surface runoff.

Complex irrigation experiments were carried out at an experimental site in the neighbourhood of the artificially created water catchment “Chicken Creek”. The irrigation rates between 150 mm/h and 210 mm/h were held constant over a time period of 20 minutes. The incoming intensities were measured as well as the raindrop-velocity and -size distributions. The surface runoff was continuously registered, soil samples were taken, and soil water potential heads were monitored using tensiometers. Surface and subsurface flow paths were identified using different tracers. The soil surface structures were recorded using a high resolution digital camera before, during, and after irrigation. Micro topography was surveyed using close-range photogrammetry.

With this experimental design both, flow paths on the surface and in the soil as well as structure and texture changes could be observed simultaneously. In 2D vertical cross-sections, the effect of initial sediment deposition structure on infiltration and runoff was observed. Image analysis of surface pictures allowed identifying structural and soil textural changes during the runoff process. Similar structural changes related to surface flow paths were found with the photogrammetric surface analysis.We found evidence for the importance of the initial structures on the flow paths as well as a significant influence of the system development. Flow paths tended to orient along initial structures and changes during the early stages of development. The amount of runoff increased from about 20% of irrigation on the first stage to 50% for the same plot one year later.

The data will be used in 2D and 3D numerical simulations of the observed surface and soil water fluxes.

Eco-pedological characterization of forestry ecosystems from North-Eastern part of Romania

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Abstract

Stability or instability of the ecosystems is determined by the reversible and permanent changes of substances, energy and informations which achieve between biotope and biocenosis, depending on the local and regional ecological specific (Mäder et al., 1997). Ecological interpretation of the soil defines, from a quantitative and qualitative point of view, the two target characteristics of the soil: trophic potential and ecological specific, the soil being able to manifests complete or restricting, seasonal and local (Bireescu et al., 2005).

The complex ecological studies of the soil resources belonging of the forest ecosystems, presented in this paper, highlighted the trophic potential under zonal and local ecological specific. Our studies were conducted on haplic chernozem (WRB, 2006) in the oak forest of Ezareni, molic salic gleysol (WRB, 2006) in the ash forest of Probota, vertic luvisol (WRB, 2006) in the oak forest with lime of Barnova and distric luvisol (WRB, 2006) in the mixed forest (beech, ash, hornbeam and oak) of Vanatori. Also, the assessment of ecological and anthropogenic impact (climate, pedological, geological) has identified and quantified, from the quantitative and qualitative point of view, the main ecological factors and determinants and the main negative ecological effects. Thus, the ecological specificity files (fig 1, 2, 3 and 4) pointed out, on the one hand, that the most ecological factors and determinants are included into the medium and high ecological size classes, ensuring a high favorability for the forestry ecosystems and, on the other hand, the main negative ecological factors and determinants, stressed by lack and excess (excessive droughty summer season, low level of summer precipitations, hard soil consistency in the summer season, fine texture and low level of soil aeration).

Fig. 1-Ecological size classes for forestry ecosystems Ezareni and Probota

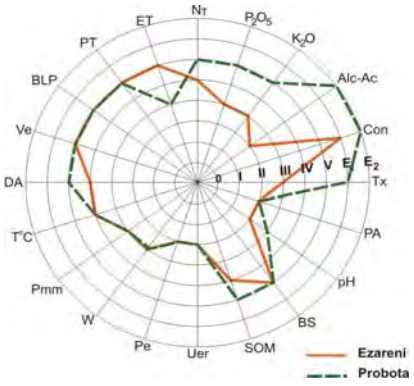


Fig. 2-Ecological favorability classes for forestry ecosystems Ezareni and Probota

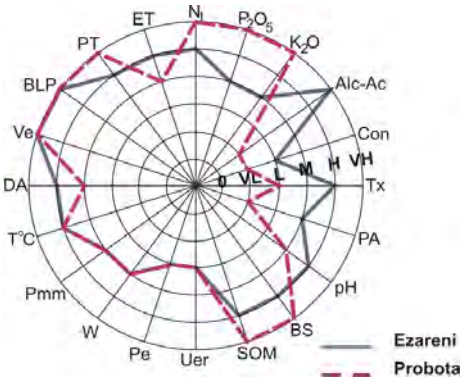
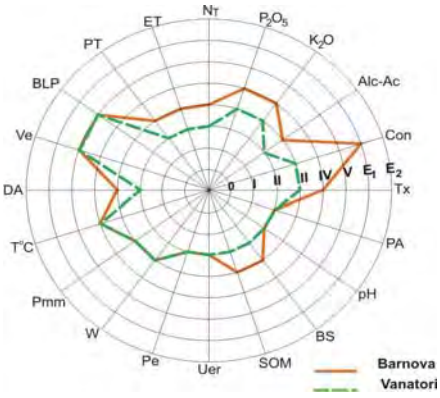
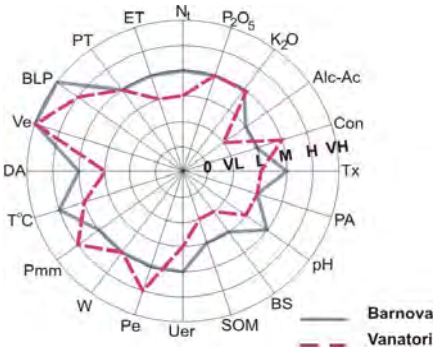


Fig. 3-Ecological size classes for forestry ecosystems Barnova and Vanatori

Fig. 4-Ecological favorability classes for forestry ecosystems Barnova and Vanatori





These, corroborated with the negative anthropogenic factor diminished the complete use of the trophic background of the soil, and the forest microclimate. The highlighted negative factors and determinants will be considered for the protection, conservation and development of the measures of ecological rehabilitation, in the context of sustainable strategies of forest management.

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Quantitative and qualitative assessment of ecological specific under conversion to organic vegetable

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Abstract

Within national development and environmental strategies, especially in recent years, more countries have taken into consideration, the solving of complex problems related to damage of environmental quality by anthropogenic impact, by use of intensive technologies. Consequently, this paper highlightes an ecological complex analysis of the soil trophicity in two locations from North-Eastern and Eastern of Romania, to Andrieşeni, in the field, under conversion vegetable and Vegetable Station of Research and Development Bacau, in the solarium and field, under organic vegetable. The soil is haplic chernozem (WRB, 2006) in the field to Andrieşeni and Bacau and hortic anthrosol (WRB, 2006) in the solarium to Vegetable Station of Research and Development Bacau.

Ecological analysis (Doran & Parkin,1994) by the ecological specificity files (Bireescu et al., 2009) pointed out that, the most representative ecological factors and determinants, are included into the medium size classes in case of conversion vegetable and medium and high size classes, in case of organic vegetable, and medium and high ecological favorability, in the both cases. The summed values of the scores for the main 10 indicators of soil quality indicate the score of Eco-Pedological Diagnose of Efective Trophicity of Soil Resources (EPDETSR) on which the qualitative assessment (very good, good, medium, satisfactory and poor) is done. Thus, in case of conversion vegetable from Andrieşeni, in the field, EPDETSR shows us a good and medium effective trophicity of haplic chernozem (64 and 54 points) (table 1).

In case of Vegetable Station of Research and Development Bacau (table 1), in the solarium, EPDETSR highlights a very good effective trophicity of hortic anthrosol (84-86 points). In the field, EPDETSR highlights a good effective trophicity of haplic chernozem (60-64 points).

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Tab. 1 - Eco-Pedological Diagnose of Efective Trophicity of Soil Resources (EPDETSR) in conversion and organic vegetable

Indicators	Grades	Andrienseni		Vegetable Station of Research and Development Bacau						
		field		solarium			field			
		eggplants	onion	tomatoes	capsicum	cucumbers	lovage	tomatoes	sweet corn	capsicum
Soil texture (% clay)	Value	36,6	34,4	35,1	37,3	34,7	41,4	36,2	34,1	33,8
	Score	6	6	6	6	6	6	6	6	6
Soil consistency	Value	very hard	very hard	friable	friable	friable	hard	hard	hard	hard
	Score	4	4	8	8	8	6	6	6	6
Soil reaction (pH_{H2O})	Value	7,0	7,4	6,2	6,4	6,6	5,8	5,9	6,0	6,2
	Score	10	6	6	6	8	6	6	6	6
Base saturation (%)	Value	90	86	92	91	93	86	84	85	83
	Score	8	8	10	10	10	8	8	8	8
SOM content (%)	Value	3,214	3,021	3,67	3,72	3,69	3,21	3,15	3,28	3,17
	Score	6	4	8	8	8	6	6	6	6
Total N content (%)	Value	0,189	0,173	0,24	0,25	0,24	0,20	0,22	0,23	0,23
	Score	8	6	10	10	10	8	8	8	8
Available P content (ppm)	Value	28	24	73	76	74	35	44	51	53
	Score	6	6	10	10	10	6	8	8	8
Exchange potassium (ppm)	Value	158	171	239	245	238	165	148	151	163
	Score	6	6	10	10	10	6	6	6	6
Air porosity (%)	Value	15	13	22	21	20	12	14	13	14
	Score	4	4	8	8	6	4	4	4	4
Biological Indicator (%)	Value	19	15	38	40	41	17	28	24	26
	Score	4	4	8	10	10	4	6	6	6
Soil type		Haplic chernozem		Hortic anthrosol			Haplic chernozem			
EPDETSR	points	62	54	84	86	86	60	64	64	64
	assess	good	medium	very good	very good	very good	good	good	good	good

Characterization of root growth dynamics in the initial phase of soil development – linking 3D sampling and minirhizotron observations

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Abstract

To characterize the role of root growth for soil development in the initial state of ecosystem development root systems of the primary vegetation growing on raw soils from quaternary calcareous sediments was studied. Two abundant plant species, Lotus corniculatus and Calamagrostis epigeios were selected and studied in detail under field conditions. A 3-dimensional root sampling procedure and observations from minirhizotron were used to link information on root distribution at high resolution of data on growth dynamics obtained from minirhizotron observations for same pioneer plant species.

The present study is focussing on the active response of root growth to heterogeneously distributed nutrient pools in soils, and will in reverse characterize the effects that root proliferation may have on the allocation of nutrients. This will provide information to what degree roots may actively change their chemical environment and how the chemical status of a soil in the initial state of soil development may drive the spatial distribution of roots. Linking data from 3D root sampling with those of the seasonal root growth dynamics will provide a unique chance to develop a dynamic root growth model for plant species prevailing in the primary state of succession. As such the model will integrate the effects caused by both plant species and soil conditions and will strive for validate and improving current soil hydrological models. At the same time it will support the assessment of root derived carbon and nutrient allocation in soils. From this perspective the linking of information from 3D root distribution and minirhizotron studies is supposed to open up new opportunities to explore the role of roots for soil development.

Mineralization not nitrogen fixation drives nitrogen turnover of the youngest soils in the forefield of the receding Damma Glacier, Switzerland.

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Introduction

Since the end of the Little Ice Age around 1850 many alpine glaciers retreated and exposed new terrain for soil formation. Therefore, glacier forefields represent soil chronosequences of different soil developmental stages and are ideal to study the related change of microbial function in soil. Particularly nitrogen as a macronutrient for plants is an essential factor for ecosystem development. Most bedrock contains no N, therefore nitrogen input by microbial nitrogen fixation or nitrogen deposition is essential, facilitating N accumulation in plant biomass and soil organic matter within a few decades (Chapin et al. 1994).

N fixation is one major source of N in pioneer sites. Kohls et al. (1994) reported that 75% to 90% of nitrogen requirements of legumes are covered by the activity of symbiotic nitrogen fixing microbes. Similarly, Schmidt et al. (2008) demonstrated the importance of N fixing cyanobacteria for the accumulation of soil organic matter. Duc et al. (2009) found a highly diverse community of non-symbiotic nitrogen fixing microorganisms in the Damma glacier forefield. There is a widespread agreement on the contribution of nitrogen fixation on pioneer habitats; however there is some disagreement on the significance of mineralization.

Mineralization was demonstrated in the very initial phases of soil development. Bardgett et al. (2007) revealed that the pioneer stage is dominated by heterotrophs, which feed on ancient and recalcitrant carbon. In contrast, Tscherko et al. (2003) found a pronounced acceleration of nitrogen mineralization only after 50 years of soil development, paralleling plant succession as well as organic matter assemblage. What is in agreement with the common assumption that autothrophic organisms like cyanobacteria, algae, mosses, and lichens are appearing first (Walker, del Moral 2003; Schmidt et al. 2008).

Although, studies dealing with single processes related to nitrogen turnover in pioneer habitats have been published (Kandeler et al. 2006; Duc et al. 2009; Nicol et al. 2006; Deiglmayr et al. 2006; Bardgett et al. 2007; Tscherko et al. 2003; Schmidt et al. 2008; Kohls et al. 1994) a comprehensive view on the development of the whole nitrogen cycle is still missing. As all processes of the nitrogen cycle are closely linked, questions concerning the overall relevance of the different transformation steps are still unanswered.

The aim of this study was to connect functional gene patterns with potential N turnover patterns and available nitrogen species, in order to detect changes in these patterns along a defined chronosequence of differently developed soils (10, 50, 70, 120 and > 2000 years). Therefore, the abundance of functional genes involved in the N cycle processes nitrogen fixation (nifH), nitrogen

mineralization (aprA, chiA), nitrification (amoA of AOA and AOB) and denitrification (nirS, nirK, nosZ) as well as potential enzyme activities of the respective processes were assessed.

Results

Along the chronosequence, soil nutrient status changed substantially. All carbon (C) and nitrogen (N) pools increased by one order of magnitude, from sample 10a to 2000a. Similarly, potential enzyme activities increased along the chronosequence. N-fixation activity was not detected in samples 10a to 70a, but ranged between 1 and 3 pmol N h^{-1} g-1 in sample 120a and 2000a. Mineralization was assessed by protease and chitinase assays. A significant increase in mineralization activity was observed along the chronosequence for chitinase and protease activity. Potential nitrification activity increased significantly from sample 10a to sample 2000a. The same pattern was observed for potential denitrification activity.

Quantitative real-time PCR (qPCR) was used to determine the abundance of functional N-cycle genes corresponding to the processes of N-fixation (nifH), mineralization (aprA, chiA), nitrification (amoA) and denitrification (nirS, nirK, nosZ). To acquire biomass independent parameters, gene abundance was related to the DNA content of the soil. The obtained parameter – relative gene abundance – serves as proxy for the proportion of the microbial community carrying the functional gene.

Gene abundance of nifH was lowest in sample 10a and strongly increased to sample 50a. Relative nifH gene abundance stepwise decreased from sample 50a to 2000a.

To target a broader range of the mineralizing community two different functional genes were investigated (alkaline metallopeptidase gene – aprA and chitinase gene – chiA). Abundance of both mineralization genes significantly increased along the chronosequence. In contrast, relative gene abundance of mineralization genes (aprA, chiA) showed tendency to decrease.

Abundance of the nitrification marker gene amoA was studied for ammonium-oxidizing archaea (AOA) and ammonium-oxidizing bacteria (AOB). While amoA AOB abundance showed no significant differences related to g of soil, AOA significantly increased. Generally, AOB was 80-times higher than AOA abundance during early succession, while AOB to AOA ratio was close to 2 in late succession. Contrary, relative amoA gene abundance AOA remained stable, whereas relative amoA AOB gene abundance significantly decreased along the chronosequence.

To quantify the denitrifying community, nitrite reductases (nirK, nirS) and nitrous oxide reductase (nosZ) genes were detected. Generally, nirK gene abundance was two orders of magnitudes higher than nirS. Gene abundance of nirK decreased along the chronosequence. In constrast, nosZ gene abundance was lowest in sample 10a and increaed towards site 2000a. Relative gene abundances showed comparable patterns for denitrification genes, except nirS, which decreased along the chronosequence.

Discussion

Several studies provided evidence for significant changes in microbial activity and community composition during soil development (Ohtonen et al. 1999; Sigler and Zeyer 2002; Nemergut et al. 2007). Our results suggest that earliest succession (sample 10a) is dominated by mineralizers, i.e. heterotrophic bacteria feeding on organic matter. While all other processes were lowest, we found highest relative activity and highest relative abundance of mineralizers in sample 10a.

Conclusion

Our results suggest that mineralization drives nitrogen turnover in very initial soil ecosystems. The process of N-fixation only gains in importance, contributing N to the soil system, after this initial mineralization dominated stage. In late succession, also nitrification and denitrification activity established and the N cycle is closed; i.e. all four processes are present.

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Runoff generation in variably structured catchments

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Abstract

The runoff in surface water systems is generated in the contributing catchment, or – in other words – the "landscape". Along its passage through the catchment, the water passes through the soil (unsaturated zone), aquifer (saturated zone) or on top of the soil surface. The flux rates, velocities and pathways of this passage determine the amount, spatial pattern and temporal dynamics of the generated runoff.

The characteristics of runoff generation processes are controlled by varieties of factors which can be classified into two groups:

- Hydro-Meteorological conditions such as rainfall features (intensity, amount), moisture content of the landscape, snow and ice conditions in the landscape;
- Hydro-ecogeomorphological setting, such as surface infiltrability, subsurface hydraulic conditions (permeability, transmissivity, fissures etc.), connectivity between the surface and subsurface, channel drainage density, vegetation density or land cover features.

This contribution presents exemplary studies of our working group from the last 20 years, where different runoff generation processes were observed. Such studies include exfiltration excess overland flow in the "Weiherbach" catchment (SW Germany) and "Torrelaribera" catchment (NE Spain), groundwater induced runoff processes in the "Großer Graben" catchment (NE Germany), snow and ice melt induced runoff in the "Fagge" catchment (Tirol, Austria), and subsurface stormflow in the "Schäfergraben" catchment (Harz, NE Germany).

Being aware that the before mentioned factors are very variable in space and time, it is evident that the actual appearance of runoff generation processes will differ in space and time. That means, first, that at a specific site in a catchment different and/or multiple runoff generation mechanisms can appear, and, second, that a certain point in time several runoff mechanisms can be active. A second important finding is that the relevance of different runoff mechanisms changes with different scales in time and space.

Therefore, static (i.e. time invariant) approaches to describe (or model) runoff generation at a catchment scale will fail as well as approaches which do not allow spatial variability or multiple occurrences or do not account for scale-dependences in space and time.

The shape of an observed hydrograph may allow the identification of the governing runoff processes for the actual rainfall runoff event. However, one must be aware, that such a hydrograph analysis is usually based on a single-site measurement (gauge) only. In general, such analysis yield equivocal, multiple solutions. That means that clear, unequivocal runoff process identification is difficult with such single-site data. Therefore, we show two complementary approaches towards unambiguous process identification, i.e. spatially distributed and/or multi-process measurements, and modeling experiments to confirm or reject process hypothesis.

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Soil water regimes of reclaimed soils in the Alberta oil sands

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Abstract

Reclaimed soils provide the substrate for plants used to revegetate reclaimed landscapes. They provide critical water and nutrient retention for sustained growth and development. Many management options are available to reclamationists in designing these reclaimed soils; including those pertaining to soil texture and organic matter. Depth of reclamation soil that must be replaced is a critical reclamation parameter and in some cases is government regulated. How the reclaimed soil is 'put together' is called a prescription. Soil water regimes of various reclamation prescriptions that have been, and are being used in the Alberta oil sands, have been studied and will be discussed. Their soil water regimes will be discussed in the context of the meteorological regimes for the study area. Key soil physical parameters that affect how these reclaimed soils retain water will be reviewed.

Application of a terrain-based distributed model to ungauged catchment: the Chicken Creek challenge

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Abstract

This study presents the main issues found in the application of a terrain-based distributed model to the Chicken Creek, as part of the large modeling and modelers comparative study conducted on this catchment. A distributed model was chosen as this was considered the only modelling approach which could be employed to exploit the limited physical information of the catchment, without any testing data. The model applied is named NetThales and it has been originally applied to catchments with climatic conditions very different from those of the Chicken Creek. Its choice was essentially subjective, based on past modelling experience. NetThales has been designed to simulate the soil moisture dynamics and runoff production in continuous mode with a small time-step and it can be implemented with any type terrain-based computational element networks (e.g. grid- or contour-based). A terrain-based distributed model couples a computational element network with a set of algorithms that conceptualise the hydrological processes at the element scale. The element network provides the structure for characterising the element-to-element variability of the parameters of the conceptualised processes and the distribution of the lateral fluxes among the elements. This study presents the decision process taken to choose: 1) the spatial resolution of the element network; 2) the model parameters; 3) the model initial and boundary conditions. The influence of the past modelling experience will be outlined.

SOM accumulation after glacier retreat: stocks, quality and mechanisms during initial soil formation

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Abstract

Global warming may have strong effects on weathering, soil formation and soil organic matter (SOM) accumulation, and lead to the retreat of glaciers resulting in the exposure of pristine glacial till to atmospheric weathering conditions. This provides a unique set-up to understand how mineral weathering and soil formation control SOM accumulation. We studied the accumulation of SOM after retreat of the Dammaglacier in the Central Alps, Canton Uri, Switzerland, about 2000 m above sea level. Due to the retreat of the Dammaglacier the proglacial area offers a time sequence from three classes of surface age (ca. 15 yrs, 60 – 80 yrs, 110 – 140 yrs). Mature soils outside the proglacial area are older than 700 years. The parent material is granitic rock which derives from the Aare-massif. The soils in the forefield are Leptosols and Regosols, whereas Cambisols have developed outside the proglacial area.

The increase of SOM stocks (organic surface layers, mineral soil from 0 – 4 cm depth and total) from the young soils (total: 65 g m^{-2}) to the 110 – 140 year old soils (total: 2285 g m^{-2}) is significantly larger as compared to the increase from the oldest forefield soils to the mature soils (total: 3726 g m^{-2}). Organic surface layers show increasing contributions to the total OC stock from 15 yrs (0 %) to 110 - 140 yrs (63 %) reaching amounts as similar to those of the mature soils (1450 g m^{-2}). In contrast to the oldest forefield soils, mature soils have accumulated the major amount of OC in the mineral soil (60%).

The OM loading of the clay fractions increases from 44 mg g^{-1} in the young soils to 190 mg g^{-1} in the 110 - 140 year old soils and to 323 mg g^{-1} in the mature soils. This leads to decreasing specific surface areas of the clay fraction as determined by N_2-adsorption (BET approach). The clay fraction minerals are dominated by illite, irregularly interstratified mica/vermiculite, and ferrrihydrite. A strong correlation is found between increasing ferrihydrite contents (determined as oxalate-soluble iron) and increasing OM contents of the clay fraction with soil formation. H_2O_2 resistant OC also increases with soil age, again strongly correlated with increasing amounts of ferrihydrite in the clay fraction. This implies a major role of ferrihydrite for the stabilization of OM during initial soil formation.

Solid-state ^{13}C NMR spectroscopy revealed the compositional changes of SOM in bulk soils as well as clay fractions. The increase of O/N-alkyl and alkyl C with soil age is due to the specific accumulation of these components in the clay fraction, whereas the OM inherited from the glacial till is rich in aromatic and carboxyl C. Formation of organo-mineral associations starts with the accumulation of O/N-alkyl C in the proglacial area, which is in line with hydrolysable neutral sugar contents of the clay fractions. Accumulation of alkyl C is detected at a later stage only in the mature soils. This is associated with a change in the C/N ratio of the clay fraction from 10 in the proglacial area to 13 in the mature soils.

In summary, initial soil formation and SOM accumulation after glacier retreat is surprisingly fast. The accumulation of SOM in the clay fraction of these soils is controlled by weathering and formation of ferrihydrite, which in turn leads to a specific accumulation of O/N alkyl C compounds during initial soil formation.

Environmental monitoring at the Chicken Creek catchment

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Abstract

Monitoring of several environmental parameters at the Chicken Creek catchment was carried out to provide basic data and time series of meteorological, hydrological, ecological and soil conditions. As samples taken on the basis of 20 * 20 m grid proved the Quaternary substrate to be relatively homogenous both horizontally and vertically, all installations were initially oriented along this grid. Due to development of structures and patterns within the catchment over time these installations were successively complemented to better represent the differentiating site conditions. In addition to these permanent installations, other measurements, records and sampling are carried out with respect to vegetation, fauna and limnology.

Microbial food web dynamics along a chronosequence of a glacier forefield

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Abstract

Microbial food webs determine the functionality and stability of ecosystems, since an efficient budget of nutrients is the basis for the initiation and stabilisation of ecosystem processes. However the successional development of microbial food webs and their role in young ecosystems is unclear. Due to a continuous glacier retreat since mid of the 19th century, glacier forefields provide an excellent opportunity to study food web development along a chronosequence of differently developed soil ecosystems.

In the present study, litter degradation and the corresponding carbon fluxes were measured along the forefield of the Damma glacier (Switzerland). ^{13}C enriched litter of the pioneering plant Leucanthemopsis alpina L. was applied at sites that have been free of ice for approximately 10, 60 and 100 years; furthermore a site outside the forefield (> 500 years of ecosystem development) was used as reference. Structure and function of microbial communities were identified by 13C analyses of phospholipid fatty acids (PLFA) and phospholipid ether lipids (PLEL).

Surprisingly, litter degradation rates were similar at all investigated sites, although total microbial biomass increased with growing stage of soil age and development. In contrast, at sites that have been free of ice for a shorter period, a high microbial activity was observed which might have compensated the lower biomass values. Once the plant derived carbon has entered the soil, a fast C-turnover and C-cycling through the microbial food web was observed in less developed ecosystems. Concerning litter degradation, a progressive specialization of the microbial community structure was detected with increasing ecosystem development.

Supression of preferential root allocation into P-enriched soil patches by mycorrhizal symbiosis

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Abstract

Vegetation is strongly interacting with other biotic and abiotic parts of a terrestrial ecosystem. Plant biomass production, vegetation composition and succession depend to a great extent on nutrient availability in the ecosystem. Phosphorus (P) is often limiting plant growth. From preliminary experiments on the field, we also know that P is growth-limiting on the Lusatian mining area in Germany. Around 80 % of terrestrial plant species establish a mutualistic relationship with mycorrhizal fungi. Mycorrhizal fungi transfer P to the plant via their external hyphae and, in turn, the plants provide the fungi with carbohydrates. Under natural settings, the P is often patchily (heterogeneously) distributed in soils. Many plant species preferentially allocate their roots into P-enriched patches to improve P uptake. In the research presented here, we aimed to investigate the interactions between mycorrhizal fungi and the preferential allocation of roots in soil with heterogeneous P distribution.

Therefore, we established a pot experiment with Lotus japonicus (Gifu ecotype). The experiment was conducted in small containers (290×290×12 mm) filled with soil. Each container was vertically divided into three sections of equal sizes. Depending on the treatment, P-fertilized or unfertilized soil was filled into the different container sections (Table 1). In the homogeneous P treatments, the three sections of the container were filled with P-fertilized soil; in the heterogeneous treatments, only one of the side sections was filled with P-fertilized soil. The experimental design included two factors (P fertilization and mycorrhizal inoculation), with 4 and 3 levels per factor, respectively (Table 1). The 4 P applications were: no P applied, homogeneous P supply (20 mg/pot), low heterogeneous P supply (6.6 mg/pot), high heterogeneous P supply (20 mg/pot). The soil used for the experiment was gamma-sterilized and either uninoculated or inoculated with pure culture of Glomus intraradices or a mixture of indigenous mycorrhizal fungi occurring on the Lusatian mining area. Four replicate containers for each treatment combination were established and the plants grown under growth-chamber conditions for 90 days: Shoot biomass production was measured and root length was separately determined for the three sections of each of the container. We defined the precision of root allocation as the root length measured in the P rich patch on the right section of the plant container minus the root length measured in the left (unfertilized) section of the container. A value higher than zero would indicate preferential root growth for patchy P. For the treatments inoculated with G. intraradices, mycorrhizal abundance in roots and soil was assessed separately for the three sections by using real-time PCR assay targeting the species specific motif in the ribosomal large subunit.

Unfertilized non-mycorrhizal plants stopped growing after few weeks and produced (on average) only 8 mg of shoot biomass, while mycorrhizal unfertilized plants produced significantly more shoot biomass (250-330 mg). Non-mycorrhizal and homogeneously fertilized plants produced similar shoot biomass as the unfertilized mycorrhizal plants (340 mg). Mycorrhizal and homogeneously fertilized plants produced 60–100 % more shoot biomass than unfertilized mycorrhizal plants. Differences in root allocation between the different pot compartments were only seen for the non-mycorrhizal plants

supplied with patchy P source at high concentration (Fig.1). Abundance of mycorrhizal fungi in the roots and in the soil did not differ significantly between the P rich and the P poor section of the container.

Results show that mycorrhizae are crucial for P uptake of L. japonicus in the investigated soil. P is limiting for biomass production both for the nonmycorrhizal as well as for the mycorrhizal plants. To our knowledge, this study shows for the first time that mycorrhizal association can suppress preferential allocation of roots into P-enriched soil.

Table 1: Experimental design

	 0 mg P/pot	 20 mg P/pot	 6.6 mg P/pot	 20 mg P/pot
No mycorrhiza	0 P HOM No myc	20 HOM No myc	6.6 HET No myc	20 HET No myc
Glomus intraradices	0 P HOM G. intra	20 HOM G intra	6.6 HET G. intra	20 HET G. intra
Natural mycorrhiza mix	0 P HOM Myc Mix	20 HOM Myc Mix	6.6 HET Myc Mix	20 HET Myc Mix

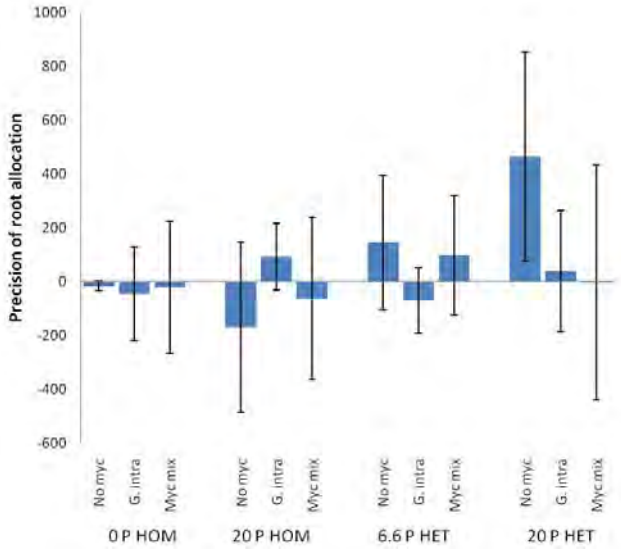

Figure 1: Precision of root allocation is calculated by subtracting root length of the unfertilized soil section from the root length in the P-enriched soil. Error bars indicate the 95 % confidence intervals.

Neutron - imaging of roots in real soil

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Abstract

Plant roots interact with processes and structures shaping the development of an ecosystem. Roots take up nutrients and water from the soil, introduce organic carbon and nitrogen, promote weathering and enhance soil structure formation, thus strongly influencing soil properties and related biotic and abiotic processes. On the other hand, root growth is depends on the spatial distribution of nutrients and water: plants preferentially allocate roots into nutrient or water-enriched patches (Robinson, 1995). For deeper understanding of these interactions, it is necessary to study the root allocation patterns over time and space. Due to the opacity of soil, this is a very challenging task. Neutron Radiography (NR) is a promising technique to visualize plant roots and thus growth patterns under in situ conditions (Conesa et al., 2009; Moradi et al., 2009a; Moradi et al., 2009b; Oswald et al., 2008). It has the advantage in comparison to other methods, to be non-destructive, which allows monitoring root growth without disturbance. Root detection by NR is limited by contrast between root and soil water content.

In a pot experiment we aimed to monitor patterns of soil colonization by a developing root system. The three main tasks of the experiment were: (1) Identification of plant species suitable for root imaging by means of NR; (2) Comparison of NR with standard root washing for determination of root length; (3) Monitoring root system development of candidate plants over several weeks.

Individual plantlets were grown in Al-containers of 27*27*1.4 cm size. The plant species were Lupinus album (Lupine), Cicer arietinum (Chickpea), Pisum sativum (Pea) and Lens culinaris (Lentil). Three replicates per plant were established. Roots were NR-imaged 19, 33, 42, 49 and 55 days after planting. On day 56 plants were harvest. Roots were carefully separated from the soil by washing, transferred to a water basin and scanned with a computer scanner. NR images were processed using “Roottracker” (a software developed at PSI by A. Kästner) to highlight the roots. Root lengths were measured both in processed NR images and in scans from washed roots using Winrhizo©.

The recovery of root length from NR images in comparison to the washing/scanning method showed considerable variation between plant species (Tab. 1). Only for lupine the root length obtained with the NR method was approximately the same. For chickpea, pea and lentil recovery of root length was low: 55 to 65% of the root length determined by washing was also found in then NR images.

To investigate root architecture and the spatial allocation of roots over time we overlaid the NR images taken at different times after planting (Fig. 1). Initially, second order roots grew away from the main roots (first order) exploring root-free soil distant from the origin. After second order roots reached the side walls of the container, third order roots were built close to the tips. Finally, second order roots were formed again filling space which had not been occupied densely before. Throughout the experiment, new roots were allocated in soil regions that had not yet been occupied by other roots. It appears that external signals allow roots to sense the presence of other roots of the same individual.

Tab. 1: Percentage of root length detected from NR-images relative to root length detected after root washing. 3 replicates per treatment.

Plant species	NR-root length recovery in %
Lupine	101 (±4)
Chickpea	65 (±5)
Pea	59 (±9)
Lentil	55(±4)

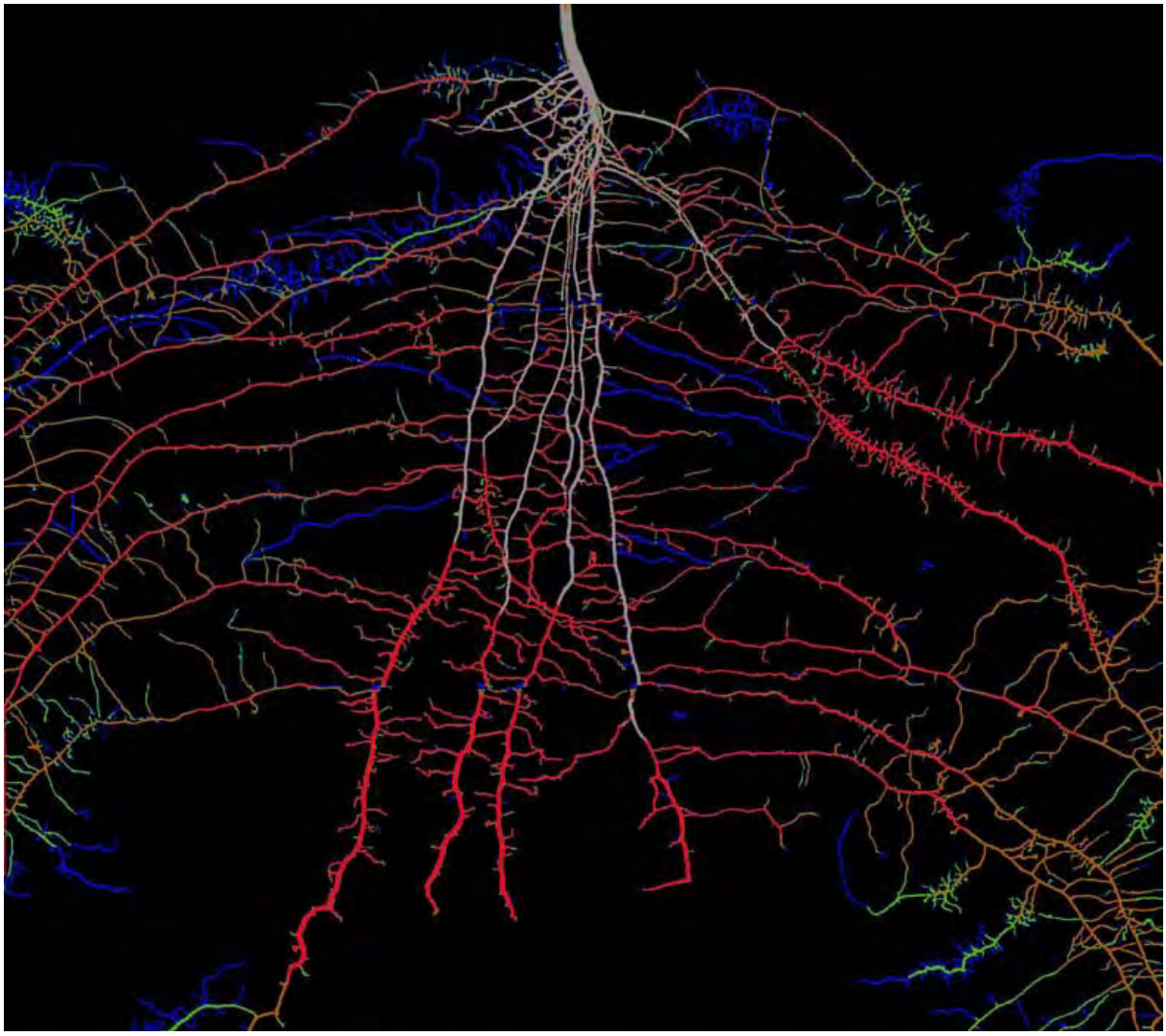

Fig 1: The colors refer to lupine-roots produced during a determined period (in days) after planting; white: 0-19; red: 19-33; brown: 33- 42; green: 42-49; blue 49-55

Model experiments to estimate hydrological characteristics of the surface soil layer of the artificial catchment area “Chicken Creek” (Hühnerwasser)

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Abstract

Several other studies already show that the infiltration characteristics of the soil surface of the Chicken Creek catchment area are distinctly different from those of lower layers. Primarily a temporarily hydraulic discontinuous layering could be thought of a cause for this. The implemented model experiments give further evidence of these special characteristics.

Large parts of the study area are evidently covered with a solid incrustation. This layer of just a few millimetres thickness has a crucial influence on the ratio between surface runoff and seepage. The model was implemented in an engineering orientated model called NASIM. For this model a soil moisture-conductivity-function was derived by matching calculated with measured precipitation-runoff timelines. This function features conductivity of just about zero near the permanent wilting point, increases rapidly with mounting water content and decreases again towards the saturation point. Hence the surface layer shows significant lower conductivity in dry status than during soaked conditions.

As a result infiltration is highly limited at the beginning of a rain event. The water content increases slowly and some time passes until the infiltration rates leave the low range. Higher infiltration rates only develop, if the precipitation persists longer.

With these soil functions a quite good match of simulated and measured runoff curves could be achieved. The use of a predefined soil function of NASIM (with maximum infiltration rate at the permanent wilting point and an exponential decreasing infiltration rate towards the saturation point) could not generate a similar result. Instead, to get results close to the observed runoff characteristics of the Chicken Creek catchment, the infiltration rate near the wilting point had to be very close to zero.

These model experiments give new clues for a better understanding of the hydrological behaviour of the Chicken Creek catchment. The propagated method of using infiltrometers or undisturbed soil specimen can only determine the hydrological parameters at steady flux in the nearly saturated range. Hence a need for determining whole functions of conductivity for actual unsteady field conditions with temporarily hydraulic discontinuous layering close to the soil surface is evidently.

Fluctuating patterns of microbial enzyme activities in an early successional stream network

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Abstract

Metabolic activity in stream networks is regulated by a combination of factors related to landscape structure, with water availability expected to be a main driver. Accordingly, we hypothesized that across the intermittent stream network of an artificial early successional watershed (Chicken Creek in Germany), microbial metabolism is highest in permanent groundwater upwelling zones. We expected lowest rates in soils adjacent to channels and intermediate rates at other in-stream sites. Substrate analogues linked to fluorescent molecules were used to measure potential activities of ten enzymes. In each season, we sampled a total of 24 sites along the courses of three stream channels. Potential enzyme activities varied little among sites, despite contrasts in long-term water availability and other environmental factors. However, seasonal variability was pronounced, with the patterns varying among the tested enzymes. Weak correlations of water chemistry and temperature with enzymatic potentials suggest that the seasonal patterns were produced by shifts in microbial communities. Whether this explanation holds or not, it is clear that enzyme dynamics at a given site were much more prominent than spatial variation across physically contrasting sites.

Fungal VS Bacterial significance for stream metabolism: a test in experimental streams

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Abstract

Fungi are important decomposers of leaf litter in streams with possible knock-on effects on other stream microbes and carbon cycling. To elucidate such effects, we designed an experiment in outdoor experimental flumes simulating sand-bed streams in an early successional state. We expected an overall enhanced microbial activity in the presence of fungi, accompanying a shift in microbial communities (fungi vs bacteria) on leaf litter. Fifteen experimental channels (4m x 0.12m x 0.12m) filled with sterilized sediment and a small amount of sterilized leaves were inoculated with one of four different suspensions: 1) stream water with bacterial and fungal communities, 2) stream water with bacterial communities only, 3) stream water without microorganisms, and 4) stream water with killed communities of bacteria and fungi. Water from an early-successional watershed was then circulated through the flumes for 5 weeks. We measured whole-system metabolism and sampled sediment and leaf litter at 5 occasions during that time. Whole-stream metabolism and microbial respiration associated with leaf litter were higher in experimental streams inoculated with fungi, reflecting faster fungal growth on leaves. There were no significant differences among the two control and bacteria-only treatments. Bacterial biomass on leaf litter and in sediment did not vary among treatments at any time, but sediment microbial respiration increased dramatically at the last sampling date in the streams receiving fungal inocula. Similarly, increases in net primary production and chlorophyll-a content were greatest in the streams inoculated with fungi. These results point to a major role of fungal communities in stream ecosystems, well beyond the direct involvement in leaf litter decomposition.

The role of soil fauna in soil formation and organic matter accumulation in post mining sites.

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Abstract

Coal mining, namely open cast coal mining cause massive devastation of the soil. This study summarizes our knowledge about effect of soil fauna on soil microstructure, chemistry, physical and microbial properties of post mining soils.

Beside plant fauna contribute significantly to soil formation namely by regulation of litter fragmentation and soil mixing. Absence of macrofauna typically result in less intensive litter fragmentation and soil mixing as a consequence most of organic matter and nutrients is stored on soil surface. Colonization of post mining sites by macrofauna and namely earthworms resulted in more intensive litter fragmentation and soil mixing by bioturbation. This yield in formation of organo-mineral A horizon in top soil layers and higher C storage in soil, increasing in water holding capacity and alternation of plant growth.

The establishment of soil fauna is affected by substrate, plant cover, and migration distance.

Observation of field- scale preferential flow in soil landscapes with kettle holes as internal drainage system

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Extended abstract

Analogous to pedon-scale phenomena (e.g., macropore flow in structured soil), preferential flow may also be defined at larger scales (e.g., Hendrickx and Flury, 2001). At field- or hillslope-scale, flow paths can develop mainly along impeding structures and other sedimentary or horizon interfaces that allow for the development of non-uniform 'local' flow fields. The preferential flow phenomenon is then related to the 'global' system of the field, hillslope, or catchment. Quantitative descriptions remain challenging. The objective of this contribution is to present field observations of larger-scale flow processes for improving conceptual understanding of relations between geo-/ pedologic structures and hydrologic functions (Gerke et al., 2010, in press).

Examples are from a typical post-glacial landscape with kettle holes (i.e., site Grünow, northeast Germany) as internal catchment systems where surface runoff and lateral subsurface flows occur. Similar post-glacial landscapes with kettle holes are widely distributed (e.g., Kalettka and Rudat, 2006) also in Poland, Denmark, and other countries around the Baltic Sea. Soil landscapes and hydrological problems are relatively similar to those of formerly glaciated regions in northern America (e.g., Hayashi et al., 2003). Water moves along the surface as runoff or within highly conductive soil regions before it enters the central depression. From there it may either evaporate or eventually lead to depression-focused recharge. Observations show that lateral flow is 'bypassing' relatively dry subsoil in the small catchment and re-wetting the subsoil in the fringe area by lateral infiltration from the pond (i.e., reversal of hydraulic gradients). Lateral hydraulic gradients were directed from the pond outwards in 2009 after snow melt and directed towards the pond in 2010. Vertical gradients were larger in 2010 than in 2009. Lateral flow towards the depression occurred on the surface or on lower permeable subsoil horizons (e.g., plow pan, till) with characteristic dynamics.

Results suggest that surface runoff is dominating the hydrological regime during the winter during snowmelt and in the summer during storm events. Ponds trap surface runoff and control seepage. Lateral exchange between pond and surrounding soil seems characteristic for the hydrological system. The field-scale lateral preferential flow can strongly control percolation and discharge and may be a possible route for ground water contamination.

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Impact of macrophyte vegetation on sediment respiration in early successional stream corridors

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Abstract

In the early successional state of sand-bed streams nascent macrophyte vegetation in the stream corridor is major source of organic carbon. Supply of organic matter from the upland catchment as in mature landscapes is scarce during open land state. This might give particular importance to in-stream vegetation as carbon source fuelling sediment associated respiration. We investigated the effect of macrophyte litter input on microbial respiration in sediments along the hydrological flow path from upland terrestrial to semi-aquatic to permanently aquatic sites of three stream corridors in the artificial catchment Chicken Creek. Dry soil and sediment was hydrated before respiration measurement to simulate the period during and after rainfall events. Organic matter was separated into the two fractions of loosely and strongly sediment associated particulate organic matter. Respiration of sediment samples was measured once with both fractions and once after removal of the loosely associated fraction. Results show the major importance of the loosely associated organic matter fraction for sediment respiration. This fraction was composed of plant fragments mainly from small roots and leaves of herbaceous plants mainly growing in the perennial sections of the early successional stream corridors. Water availability was a driving factor for plant colonisation and growth resulting in higher plant production in the perennial section of the early successional stream corridors. In-stream macrophyte vegetation as new source for a higher level of microbial activity indicates the successional transition from open land into macrophyte state within the stream corridors. Thus from the landscapes point of view, stream corridors could be regarded as pioneers of succession within the whole catchment.

Sediment disturbance depth affects stream metabolism in sand-bed streams

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Abstract

In sandy bed sediments water flow causes complex spatial and temporal patterns of sediment disturbance with varying depth of scour and fill and well known effects on benthic organisms. Poorly known, however, are effects on whole-system metabolism resulting from different depths of sediment scour and fill. Streams in early successional landscapes where surface run-off following rain events is the most important discharge, are especially characterized by frequent sediment disturbance of different depths. We assessed effects on whole-system metabolism by manually disturbing sandy sediments of experimental outdoor channels to 1 or 4 cm depth at an early (day 11) and later stage (day 31) of stream succession. Half of the channels were protected from light to separate effects on autotrophic and heterotrophic metabolism. Neither shallow nor deep sediment disturbance affected net community production in the early successional stage, whereas both induced a decline in production after disturbance in the later stage. Net community respiration during the early stage was also unaffected by sediment disturbance, but it was higher in channels exposed to daylight. In the later stage, effects of sediment disturbance overrode light effects, with higher respiration rates after deep compared to shallow disturbance. At ratios of production to respiration (P/R) <1, sediment disturbance had no effect on P/R. At the later stage, however, when P/R was >1, the deep, though not shallow, disturbance temporarily reset P/R to <1. These results indicate that light-disturbance interactive effects on stream metabolism depend on sediment disturbance depth.

Bacterial growth limitation during primary succession in the Alps

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Introduction

In contrast to plants, which are usually limited by N or P, soil bacteria are usually carbon limited in soils (Paul and Clark 1996). However, on very young soils the total amount of both C and N is very low, as they have to be biologically fixed or added by deposition in contrast to other nutrients that are present in the parent material. There are no standardised extraction methods available to determine microbial available C, N or P. By adding C, N and P to the soil and study the bacterial response their relative availability can, however, be estimated. It will be possible not only to tell which nutrient has the lowest relative availability at each step during this succession, but also have indications of the relative availability of the second limiting nutrient.

In this study we investigated limiting nutrients for bacterial growth during early stages of soil development (9-139 years) on the glacial forefield of the Damma glacier in Switzerland. We studied factors limiting bacterial growth by adding C, N and P to soil samples and measuring the bacterial growth response.

Hypothesis

1) The soil will become more C-limited with age as compared to the second limiting nutrient, 2) The response to C addition should be related to the C:N ratio or total C: extractable P ratio in the soil.

Method

The Damma glacier is situated in the Canton of Uri in the Swiss Alps. The Damma glacier has retreated approximately 1000 m since about 1850 (Gletscherberichte, 1881-2002). During this period the retreat has been interrupted, and the glacier advanced between 1911-1928 and 1972-1991. Thus, the forefield can be divided into three areas: (1) less than 17 years (site 1-4), (2) 58-81 years (site 5-16) and (3) older than 109 years (site 17-21), each forming a gradient in time with the youngest soil nearest the end moraine/ice. Soil samples were collected in September 2009 from the top 5 cm of the mineral soil. The soil was sieved fresh (2mm) and analysed for total, C and N as well as for extractable P (0.5M $NaHCO_3$).

Two grams of fresh soil was put into 50ml centrifuge tubes. Glucose, $NH4NO_3$ and K_2HPO_4 was added and one control received no nutrients (No). The nutrients were added as water solutions (totally 40µl g^{-1} soil). The samples were then incubated for 40 hours at 20°C. Bacterial growth was then determined with the leucine incorporation method described by (Bååth et al. 2001).

Results

Soil C increased within each part of the fore field (fig 1). Total soil N increased in a similar way as soil C and soil C and N were closely correlated ($R2 = 0.992$, $p < 0.001$). The soil C:N ratio was not correlated with the age since deglaciation or the distance to the closest younger end moraine/ice

except for the old part of the forefield (sites 17-21), where the C:N ratio decreased with distance to the 1928 moraine. The available P increased significantly in the young part with distance from the ice (p=0.032) but not in the middle or old part.

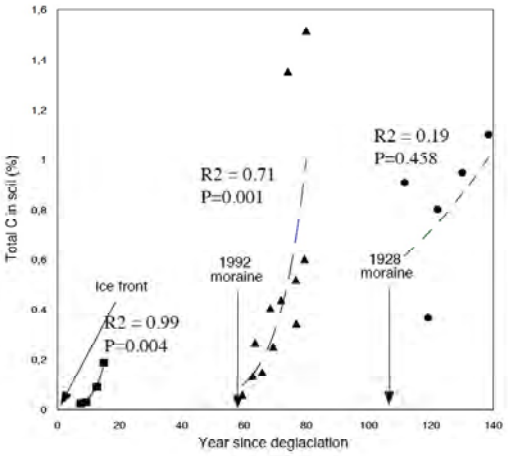
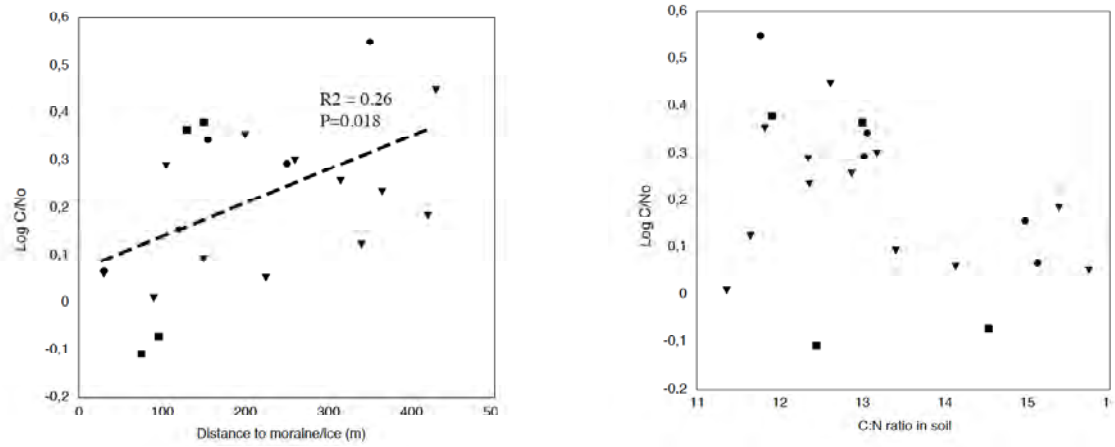


Figure 1. Total soil carbon in the soil verses years since the soil was deglaciated. Arrows indicate where the end moraines are situated.



a b

Figure 2. The increase in bacterial growth due to C addition as compared to the no addition control (C/No ratio) versus distance to the closest younger end moraine/ice (a) and the C/No ratio versus the soil total C:N ratio (b). When the soil C:N ratio is above 13.4 (vertical line) there was no strong response to C addition.

We found no indication of a bacterial growth response after adding N or P in any site. The mean effect of adding N (the bacterial growth ratio after adding N as compared to the no addition control, N/No) was 0.91 (SD=0.24) and for P 1.22 (SD = 0.35). The growth response of the bacteria due to C addition as compared with the no addition control (C/No ratio) increased with increasing distance from the closest younger end moraine/ice (Fig. 2a, R2=0.26, $p<0.05$). An increase was also found for the separate 3 gradients, being significant ($p<0.05$) for the youngest and oldest gradient. In younger soils, nearest to the end moraine/ice, there were no growth response to adding C (sites 1, 2, 5, 7 and 17), The presence of a strong response or not to C addition appeared to at least partly to be dependent on the C:N ratio in the soil (Fig 2b). The C/No ratio for bacterial growth was significantly lower for soils

with a C:N ratio above 13.4 than below (t-test, $p < 0.01$). There was a positive correlation between the C/No ratio and the total C: extractable P ratio ($p=0.013$).

Discussion

The increases in soil C and N concentrations, which result from the build up of organic material in the soil at the Damma glacier forefield, were not directly correlated to the age since deglaciation (Fig. 1). The variation in soil C and N content strengthened the concept of 3 separate gradients with distance from the end moraine/ice as a reasonable proxy for soil age and not one gradient related to age since deglaciation.

The bacterial growth response to C addition as compared to the no addition control (C/No ratio) increased with increasing soil age (Fig. 3a), supporting our first hypothesis. Since neither N nor P affected bacterial growth rates, we thus conclude that except in the youngest soils (see below), bacterial growth was universally C limited throughout the gradient.

Limitation by a nutrient is an absolute trait in that it is either limiting or not (von Liebig 1855). However, after adding C to a C-limited soil, bacterial growth will increase until limited by another nutrient. Thus, the extent of growth response after adding C will indicate the availability of the secondary limiting nutrient. The increasing response after adding C with soil age (increased C/No ratio) thus indicates that with soil age the relative availability of the secondary limiting nutrient increased compared to the C availability. Consequently, bacterial growth became “more C limited” with soil age.

In the youngest soils there was no response by bacterial growth from adding any single nutrient. The lack of response to C is connected to a high C:N ratio in the soil (Fig. 2b) and the response to C addition was not negatively related to the total C : Extractable P ratio indicating that N rather than P is the second limiting nutrient. In theory a shift from C limitation to N limitation should occur at a C:N ratio somewhere between 8 and 16 based on that the bacterial C:N ratio is between 4 and 8 and that about 50 % of the carbon taken up is respired (Paul and Clark 1996, Kaye and Hart 1997). However, even soils with C:N ratios as high as 50 have been found to be C limited for bacterial growth (Paul and Clark 1996, Demoling et al. 2007). The reason that we detect a lack of C limitation at a much lower soil C:N ratio, in accordance with the theory, might be due to that the organic C in these young soils is of a more available form compared with old, more mature, soils of higher organic matter content. In old soils physically and chemically recalcitrant soil organic matter has been accumulating resulting in the available soil C/N ratio being much lower than that reflected by total C and N concentrations measured in the soil. The fact that even for some soils of low C:N ratio we still did not detect any growth increase due to C addition further emphasises that total C:N ratio generally is not a valuable measure to infer limiting substances for bacterial growth in soil, underscoring an important difference between aquatic (Elser et al. 2007) and terrestrial systems.

At the young sites the soil bacteria appeared to be co-limited by both C and N. This has earlier been found in arctic soil and forest soils low in nitrogen using the Leu incorporation technique (Demoling, Rinnan, Bååth, unpublished) and by Yoishitake et al. (2007) in young soils near a retreating glacier on Svalbard based on respiration measurements. Co-limitation of bacterial growth is also a common phenomenon in water (Elser et al. 2009). It suggests that when there is a shortage of N there will also be a simultaneous shortage of C. Why do we then not find that the bacteria were N limited in young soils, and that this would cause a build-up of available C in the soil? It could be due to bacterial

respiration without growth in the soil or fungal activity. To better understand the co-limitation of bacteria and the role of the fungi in this, further studies will be performed where we will add combinations of C, N and P and measure the bacterial response as well as the fungal response.

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Quantifying the meaning of locally measured soil moisture for the runoff response considering three nested catchments, Eastern Ore Mountains

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Abstract

Runoff formation, infiltration and evapotranspiration are mainly controlled by soil moisture. The experimental characterisation of near surface soil moisture patterns and their controls on runoff formation is, however, still largely untapped. Using two TDR clusters installed in the upper Wilde Weißeritz catchment (Eastern Ore Mountains, Germany/Czech Republic), we investigated how well "the catchment state" may be characterised by means of distributed soil moisture data observed at the field scale. A grassland site and a forested site both located on gentle slopes were instrumented with two Spatial TDR clusters (STDR) that consist of 39 and 32 coated TDR probes of 60 cm length.

The interplay of soil moisture and runoff formation was interrogated using discharge data from three nested catchments: the Becherbach with a size of 2 km², the Rehefeld catchment (17 km²) and the superordinate Ammelsdorf catchment (49 km²).

Multiple regression analysis including observations of antecedent precipitation indexes, pre-event runoff, soil moisture and different explanatory characteristics derived from meteorological data were employed to predict runoff coefficients with linear models. On the small scale we found a strong correlation between the average soil moisture and the runoff coefficients of rainfall-runoff events, which almost explains as much variability as the pre-event runoff. The soil moisture measured at the forested side compared to the grassland side has more descriptive character concerning its location is closer to the riparian zone. There was, furthermore, a strong correlation between surface soil moisture and subsurface wetness. With increasing catchment size, the explanatory power of soil moisture reduced, but it was still in a good accordance to the former results. It is remarkable that even for the gauge Ammelsdorf which has a factor of 105 larger area than the sampled area of the soil moisture, soil moisture still has a high explanatory character. In combination with intensity, duration and, lag time of precipitation events up to 90 percent of the variability can be explained. The validity of the often used antecedent precipitation indexes to describe initial conditions was poor. The multivariate analysis indicated that the proposed sampling strategy of clustering TDR probes in typical functional units is a promising technique to explore the soil moisture control on runoff generation and can be an important link between the scales. Long term monitoring of such sites could yield valuable information for flood warning and forecasting by identifying critical soil moisture conditions for the former and a better representation of the initial moisture conditions for the further.

Initial development of carbon fluxes along a soil chronosequence of a glacier forefield – a labelled litter experiment

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Abstract

Alpine areas are strongly affected by increasing temperatures. In the Swiss Alps, 90% of the glaciers have a negative mass balance, which leads to the exposure of fresh rocks on unvegetated land surfaces. Young soils developing in glacier forefields are accumulating C, probably more than soils in old 'mature' ecosystems, where higher C inputs are balanced by higher decomposition rates.

The main goal of this tracer study is to investigate the influence of initial soil development on the C cycling in a glacier forefield. Plant and microbial communities change with soil age, and weathering as well as C accumulation alter the 'activity' and 'sorptivity' of mineral surfaces, which all affect soil organic matter (SOM) turnover. To identify the fate, the turnover and the transformation of new litter C and old SOM in different soil ages we added isotopic labelled litter (2.5g Leucanthemopsis alpina with $\delta^{13}C$ = +110‰ and $\delta^{15}N$ = +900‰) in June 2009 along a chronosequence (10yr, 70yr, 120yr) at the granitic Damma Glacier forefield, Switzerland. At every point along the chronosequence soil respiration was measured as well as gas and soil water samples were taken every week June to October 2009. Both contents and isotopic signatures of C were analysed in SOM, leached DOC and respired CO_2.

First results show an exponential increase in soil C within each soil age and a gap between the different soil ages. The annual rates of soil respiration, compared to net C accumulation, indicate that the latter is an order of magnitude lower than the annual flux of C through the system. Soil respiration increased five fold with increasing soil age. The signal of the labelled litter in soil-respired CO_2 declined rapidly within the first month after litter addition in the whole glacier forefield. At the younger sites, the contribution of litter to the soil CO_2-efflux was three times higher compared with the older sites. This must be the result from higher respiration rates of old SOM as well as root respiration by the greater stock of living biomass at the older sites. Leaching of DOC increased similar to soil respiration along the chronosequence. The seasonal pattern shows a flush bulk after litter addition and rewetting peaks by rainfall at all soil ages. The fraction of litter derived DOC was quite dominant at young sites but not considerable distinctive at the older one. We reasoned that the litter derived C is retained and replaced by old C in DOC. In summary, the development of C- cycling coincides with increasing biological activity. Only a small fraction of the plant C inputs is accumulating in soils.

Vegetation-soil feedbacks control early ecosystem development in water-limited environments

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Abstract

In water-limited ecosystems, vegetation is strongly linked to soil moisture dynamics through two-way interactions often referred to as feedbacks. In particular, vegetation influences soil moisture dynamics by moderating bare soil evaporation and root water uptake. In addition, root intrusion and improved macroaggregation in the rhizosphere enhance infiltration and hydraulic conductivity. Conversely, the resulting soil moisture dynamics influences vegetation growth and survival. While the role of these feedbacks in the development of self-patterned vegetation such as 'tiger bush' is well-documented, the nature of vegetation temporal dynamics caused by such feedbacks remains poorly understood. Conventional short-term field monitoring, often fail to detect these temporal patterns due to long timescales involved.

However, empirical observations on artificially-reconstructed ecosystems such as rehabilitated mine sites, and palaeoecological studies based on vegetation proxies such as pollen and fossil abundance offer great research opportunities to observe these subtle temporal patterns of vegetation. So far, two main findings demonstrating nonlinear temporal patterns of vegetation have emerged from such studies; (1) observations of temporal evolution of vegetation from time zero showed that damped behaviour and overshooting, whereby biomass productivity in the first decade exceeds long-term values are prevalent on revegetated rehabilitated mined sites and cleared forest catchments (Fig. 1); and (2) analysis of fossil and pollen abundances in semi-arid ecosystems reveals cyclic temporal patterns reflecting vegetation periodicity (Gillson, 2004). However, mechanisms explaining such temporal patterns are either lacking or divergent.

Here, we propose a unifying mechanism based on vegetation-soil feedbacks as fundamental drivers of these transient and long-term temporal patterns. To explore this hypothesis, we developed and investigated a simple model based on empirically-observed vegetation-soil interactions. In particular, the model considers vegetation effects on bare soil evaporation, infiltration, root water uptake and hydraulic properties, and their resulting impacts on soil moisture dynamics and vegetation growth. For the first time, we demonstrate that vegetation-soil feedbacks can cause the emergence of damped oscillations and biomass overshooting consistent with empirical observations (Fig. 2A and C). For certain parameters, we show that the model converges to periodic oscillations (limit cycles), similar to those observed in palaecological studies (Fig. 2B and D). Along a rainfall gradient covering hyper-arid, semi-arid and sub-humid conditions, we observed threshold-like transitions of vegetation, whereby the system switched from bare state (hyper-arid) to damped oscillations and limit cycles (semi-arid), and ultimately to a fully-vegetated state (sub-humid) (Fig. 3). Overall, despite its simplicity, the model captures the diverse temporal patterns of vegetation observed in water-limited environments, thus providing a simple unifying mechanism. Understanding these feedbacks may provide some crucial insights for ecological applications such as restoration of disturbed ecosystems.

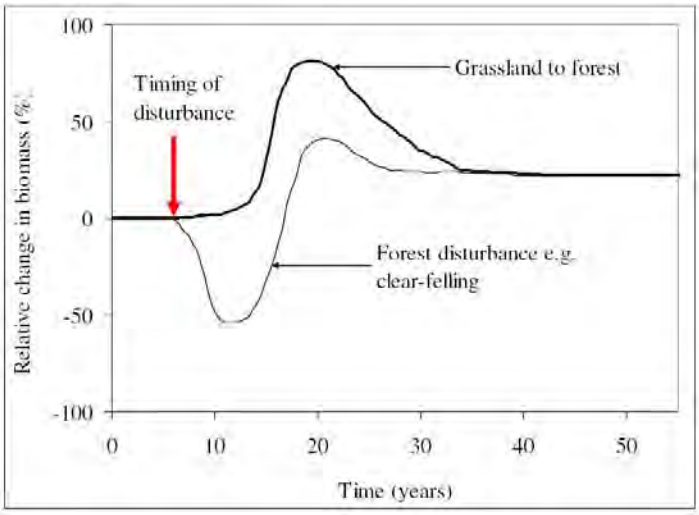

Fig. 1: Damped behaviour and biomass overshooting observed on vegetation ecosystems recovering from disturbances. Catchment evapotranspiration (ET) and leaf area index (LAI) were used a proxies of biomass productivity (modified after Donohue et al., 2007).

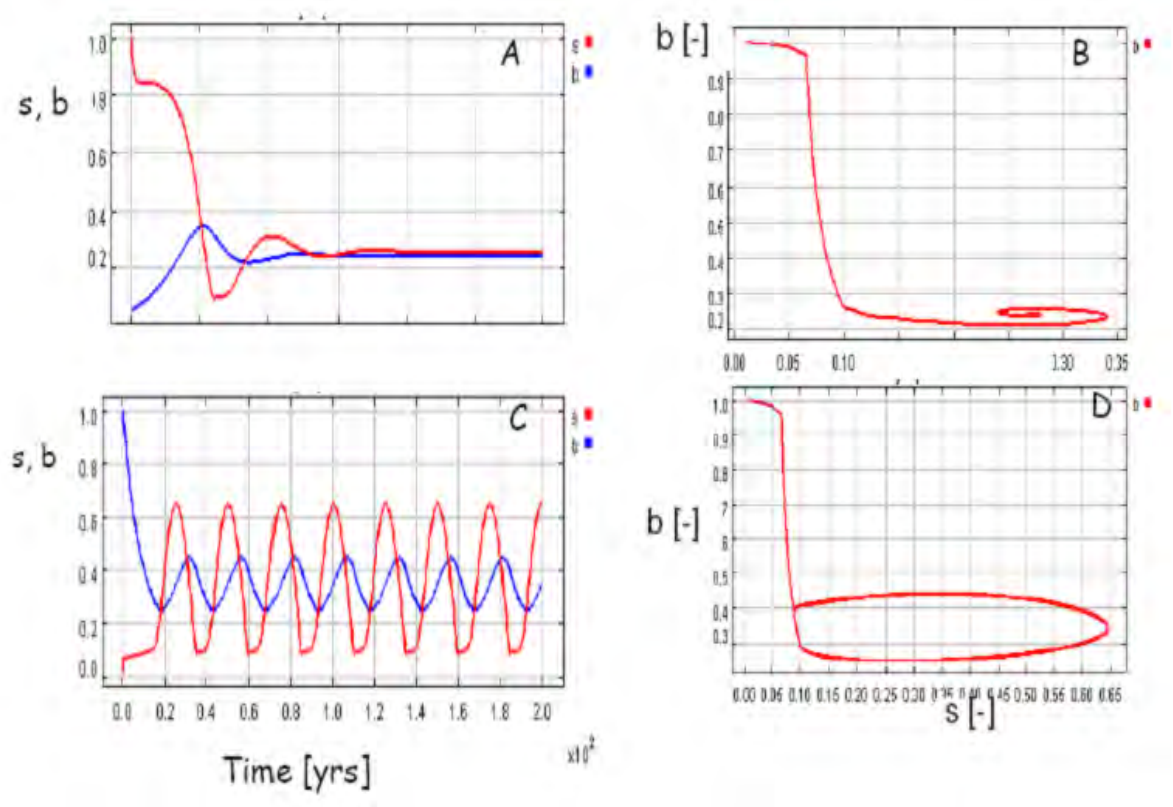

Fig. 2: Temporal dynamics (A and C) and phase plots (B and D) of biomass and soil moisture. (A-B) damped oscillations to a stable point. (C-D) periodic oscillations (limit cycles)

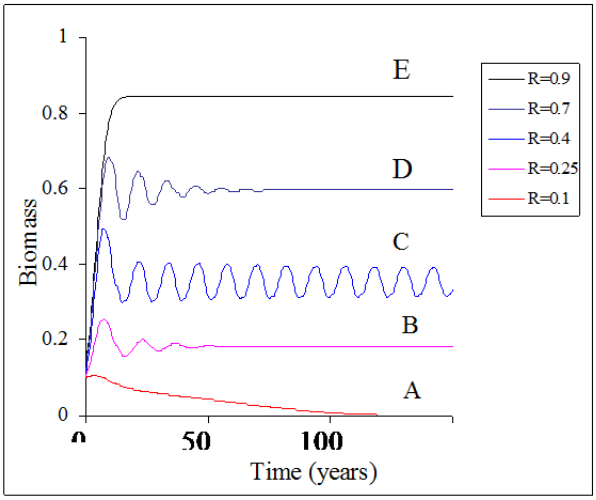

Fig. 3: Vegetation dynamics along a precipitation (R) gradient. Bare (desert) state in hyper-arid conditions (A), damped oscillations (B and D) and limit cycles (C) in semi-arid conditions and fully vegetated state (E) under sub-humid conditions. The rainfall parameter, R values indicate relative wetness.

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Macrophytes as “landscape modulators”: the ecological role in small Mediterranean streams

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Abstract

“Initial development stages of geo-ecosystems are characterized by highly dynamic abiotic and biotic processes, which result in the rapid formation and alteration of structures…” This short background taken from the SFB/TRR 38, describes well a typical Mediterranean-Climate Stream ecosystem (MCS). These ecosystems are an outcome of a Mediterranean climate which is characterized by mild rainy winters followed by a long period (4 to 6 months) of hot and dry summer (Hobbs et al., 1995). Correspondingly, MCS are physically, chemically, and biologically shaped by the sequential, seasonally predictable events of flooding (late fall and winter) and drying (late summer and fall), that vary markedly in intensity on a multi-annual scale (Gasith & Resh, 1999). Winter floods are the stream's 'reset mechanism', that scour accumulated sediment and debris, wash away in-stream and encroaching riparian vegetation and redistribute stream-bed substrate and organisms (Resh et al., 1990; Lake, 1995, 2000; Gasith & Resh, 1999). In contrast to the flashy "pulse" nature of floods, drying is more prolonged and gradual "ramp-shaped" process (Boulton, 2003). It involves a gradient of events from reductions in flow, through formation of isolated pools, to complete channel drying (fig. 1). Both floods and droughts can destroy habitat patches and create new ones that are then colonized by the biota (Lake, 2000; Fritz & Dodds, 2004). Therefore these ecosystems can be regarded as being under a continuous cycle of destruction (autumn/winter) and re-growth (spring/summer). For instance, flood events can limit plant growth (Riis & Biggs, 2003). In contrast the long process of desiccation (that in Mediterranean regions is usually combined with elevated temperatures, abundance of sunshine and nutrient loading from agricultural lands), can result in a relatively long period of favorable conditions for plant growth (Gasith & Resh 1999). In streams with no or few flood events, the vegetation can develop to maximum abundance (e.g., 100% cover; Kaenel & Uehlinger, 1999). In our study we followed the development of watercress (Nasturtium officinale), from early spring through mid summer. For example, percent cover (blockage factor) dynamic revealed a hump-shape pattern (fig 2) that increased for ca. 80 days at a rate of about 1% per day, reaching a plateau for additional 40 days and than collapsed.

The unique hydrological pattern of MCS presents an opportunity for testing the structuring role of in-stream vegetation as ecosystem engineers that act as ‘landscape modulators’ (LM). This term was first introduced by Shachak and co-authors (2008) describing organisms that modify the environment by their own structure (e.g. desert shrubs). Ecosystem engineers include taxonomically unrelated key organisms (e.g., marsh burrowing crab, desert isopod, and beaver), that can have an effect on the ecosystem. 'Ecosystem engineering' can be described by three central processes: landscape modulation, resource modulation and community (species) response. In fluvial ecosystems macrophytic vegetation can modify resources such as flow and habitat heterogeneity, with cascading impacts on biotic structure and interactions (Sand-Jensen 1997). For example, by retarding flow dense patches of macrophytes can reduce turbulence and velocity (Green 2005), increase flow variation, water depth, and wetted area above the vegetation patch (Champion & Tanner 2000). This process

can lead to enhanced trapping and settling of suspended particles and modification of stream bottom (Sand-Jensen, 1998). In our study we used an in-situ portable flume experiment (after Gibbins et al, 2007) and found that dense patches (>200 gr AFDW) of submerged watercress have the ability to reduce flow velocity up to 90% then the un-vegetated habitat (fig 3). Moreover, we found that when macrophyte exceeds 75% cover of the channel, accumulation of coarse sediment (>200 micron) in the stream bottom is significantly enhanced (fig 4). Positive correlation between macroinvertebrate abundance and richness and plant biomass is well documented (e.g., Collier et al, 1999; Strayer et al, 2003). Our findings support this effect of the vegetation on community richness, as demonstrated in fig 5.

Overall, present knowledge supports the conclusion that in-stream vegetation acts as 'ecosystem engineer', and its importance in aquatic systems "far exceeds their direct role in primary production of organic material oxygen" (Sand-Jensen 1997). However, so far the role of EE as modulators of fluvial landscapes during the early stages of development (e.g. after a sever flood or complete desiccation of the channel) has not been well studied, even though examples from other ecosystems have been documented (for example review of soil invertebrates by Lavelle et al 2006). Thus, additional field work as well as experimental data is needed in order to fill this knowledge gap to better understand the contribution of EE in the early stages of ecosystem development, such as Mediterranean ones.

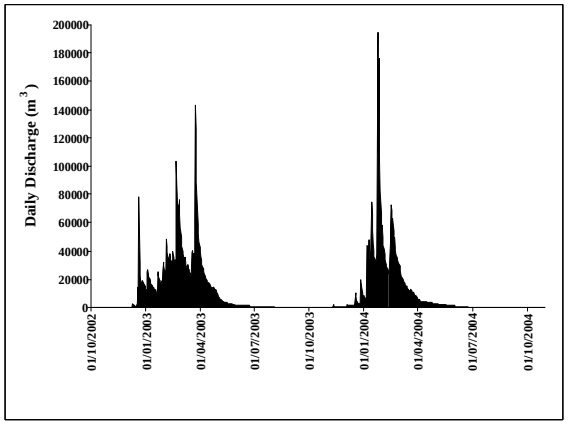

Figure 1: An example of an annual daily discharge pattern in typical Mediterranean climate stream (Ha'Shofet 2002 – 2004)

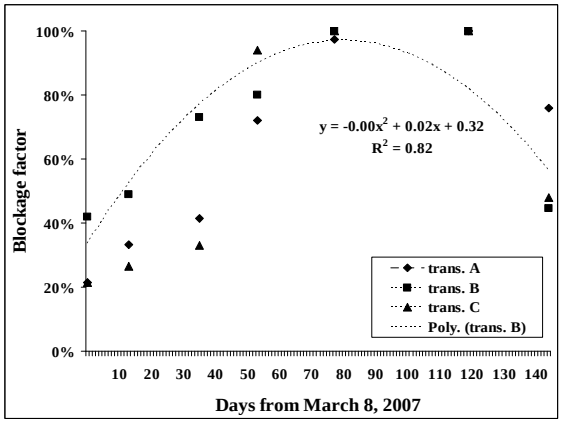

Figure 2: Temporal change of percent cover (blockage factor) of water cress in 3 cross-section transects. A polynomial fit curve (R^2=0.82, n=7) is shown for transect B.

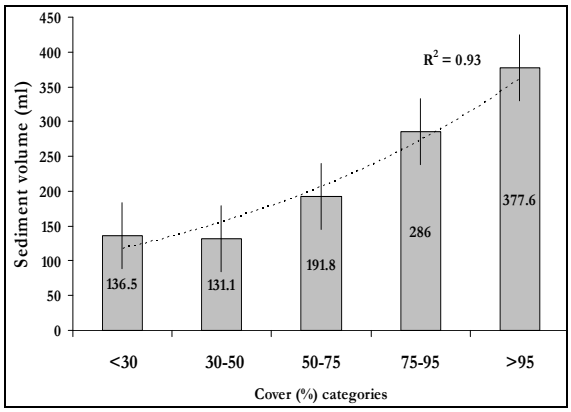

Figure 3: In-situ flow retardness (% velocity reduction) by watercress as a function of plant biomass.

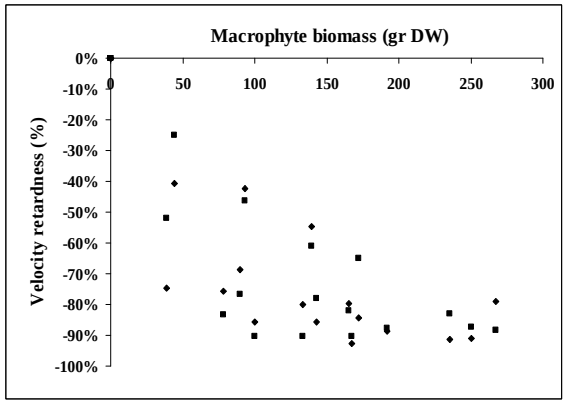

Figure 4: Sediment accretion (volume) as a function of plant cover (%), an example of habitat modification by a landscape modulator.

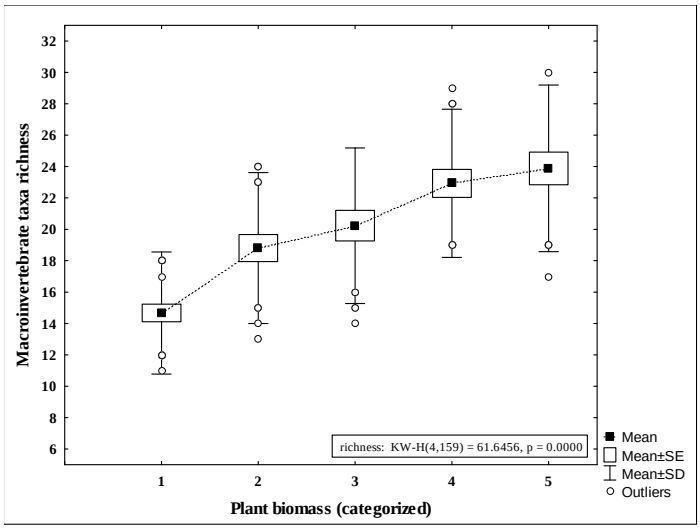

Figure 5: Relationship between macroinvertebrate taxa richness and plant biomass (gr AFDW / m^2). The latter is categorized as follows: 1= <5; 2= 5-49; 3=50-99; 4=100-199; 5=>200

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Modelling the emergence of surface erosion rills in an artificial catchment

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Abstract

Surface erosion rills are dominant structures in young developing ecosystems, affecting water flow by channelling surface runoff, and changing soil infiltration capacity due to deposition of eroded material. Water balance and drainage pathways of such ecosystems cannot be understood based on soil hydraulic properties and subsurface flow models alone without considering emerging networks of erosion rills.

To successfully model the hydrology of a slope system, it is indispensable to simulate the generation of the erosion rills adequately. We chose the artificial catchment 'Chicken Creek' near Cottbus (Germany) as experimental area for this modelling study. The construction of the catchment with a surface area of 6 ha and an average slope of 3.5% was finished in 2005 and since has been left to an undirected primary succession. An erosion rill network formed on the surface of the catchment during recurring rainfall events in the last few years. Based on aerial photographs the evolving network was quantified with respect to length, rill depth and connectivity.

We modified two model approaches to simulate the emergence of the erosion rills in the artificial catchment. In the first approach we implemented erosion and deposition in a surface runoff model based on Manning's equation. Erosion was described as a function of shear stress whereas deposition was calculated using the sink velocity of medium sized sand particles. The second approach, a self-organised critical network approach, simulated soil erosion and deposition based on the exceedance or undercutting, respectively, of local critical shear stress thresholds. We discuss the pros and cons of the two approaches and compare the predictions with observations to deduce the mechanisms determining the erosion rills.

Primary succession of the soil micro fauna in Chicken Creek

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Abstract

At the experimental site “Chicken Creek” (Spremberg, Germany), undisturbed primary succession of the nematode and tardigrade community is investigated. We here report the results of the first 4 years after initial soil deposition in 2005. During the first two years of succession, nematodes and tardigrades occurred only sporadically and in rather small numbers. From October 2007 densities steadily increased, and nematode numbers were reaching counts reported from mature soils (1.6 106 ind m^{-2}). Also numbers of nematode species increased during succession, but were still low in Oct 2009 (10 species per sample, 39 species per site, and only 97 identified species over all 4 years at “Chicken Creek”), indicating that the “Chicken Creek” mine spoils are poor in terms of nutrient availability and micro climatic conditions. This basal status of the “Chicken Creek” spoils is further confirmed by the faunal profile, based on the indicator importance of functional guilds of nematodes (“weighted faunal analysis”), which suggests that the flow of resources into the food web system as well as the prevalence and abundance of higher trophic level organisms is dramatically low in 2005 and slowly increasing during the initial ecosystem development. Nematode biomass mainly consisted of bacterivores in the beginning, and from Oct 2007 on, fungivores, omnivores (algal feeders) and plant root feeders gained importance, reflecting the presence of food sources in the succession of “Chicken Creek”. Correspondences of nematode and tardigrade community data and environmental parameters are discussed.

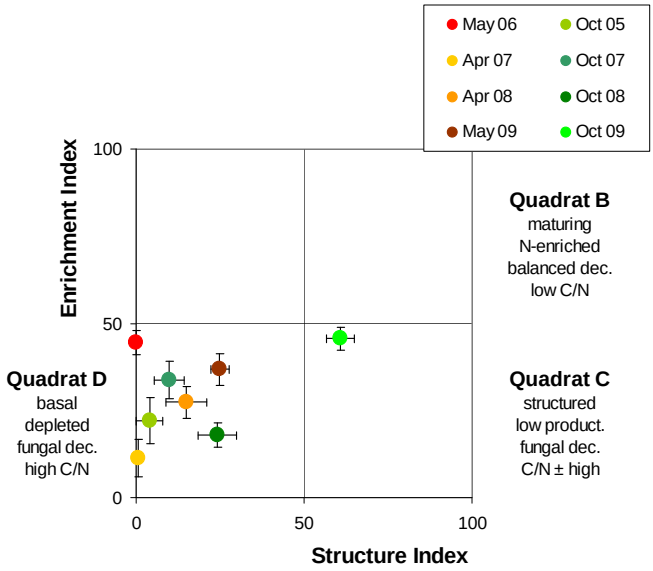

Fig. 1 Faunal profile of the “Chicken Creek” food web status from 2005 to 2009 based on nematode functional guilds

The human factor in catchment modeling: from a priori prediction to calibration

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Abstract

Ten modellers were invited to predict, independently from each other, the discharge of the artificial Chicken Creek catchment in North-Eastern Germany for a simulation period of three years, providing them only with soil texture, terrain and meteorological data. The modellers had however the opportunity to visit the experimental catchment and to inspect the aerial photos of the catchment at its initial development stage.

This study was focussed on how different modellers approach and solve the problem of predicting discharge in ungauged catchments. Of particular interest were (1) the choice of the model structure; (2) the selection identification of model parameters; (3) the identification of the initial and boundary conditions.

The first lesson learned from this study was that the modeller per se is part of the modelling process and has a major impact on the model results, particularly for a priori predictions in ungauged catchments that have a high degree of freedom in making modelling decisions. The modeller's decisions during the phase of model implementation and parameterisation are deeply influenced by their experience from previous modelling studies. The modellers primarily applied process-based models to exploit the available data concerning the physical catchment. Doing this they were better prepared to handle missing information on internal state variables and fluxes.

The second lesson from this study was the role of identifying the dominant processes in the catchment. We anticipated that the a priori modelling task would be easier using an artificial catchment, where heterogeneity was expected to be negligible and process dynamics simpler than in catchments that have evolved over a longer period of time. The modelled results converged with a stepwise supply of more information to the modellers, but the differences are amazingly large. This model comparison showed also that even a small artificial catchment exhibits heterogeneity which

leads to similar modelling problems as in natural catchments and, above all, the assumptions largely determine the outcome of the prediction.

We will present on the conference: the influences of modelling experiences, the impact of field visits and workshop on predictive results and results with calibration data sets from first prediction up to calibrated results.

How does spatially varying saturated hydraulic conductivity effect hydrological patterns and processes in the artificial Chicken Creek Catchment?

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Abstract

In order to understand the dynamic of the hydrological processes within the catchment, a thorough knowledge concerning the effects of spatial variability of soil properties on hydrological pattern is indispensible. However, our process understanding is still limited because those effects are generally difficult to observe, especially when occurring below the surface. In order to improve our limited understanding of those effects, the application of process-based spatially distributed hydrological modelling tools is promising. By considering spatial variability of soil properties in such models, effects on hydrological patterns and the underlying processes can be identified.

The artificial Chicken Creek Catchment (6 ha) situated in Germany is characterized by a unique hydrological behaviour, differing from naturally evolved catchments. The catchment was constructed by artificially deposing sediments which results in spatial structures leading to a large spatial variability of saturated hydraulic conductivity. The spatial variability of the saturated hydraulic conductivity is a key factor for various hydrological processes. In addition to sand deposits, a lateral clay dam was constructed in the lower part of the catchment which inhibits lateral drainage. Combing spatial variability of soil hydraulic conductivity and the clay dam leads to rising groundwater tables observed since catchment construction.

To analyse and evaluate these patterns on the hydrological behaviour, the process-based distributed Water balance Simulation Model (WaSiM-ETH) was applied. In a first step, the impact of applying a physically based two-dimensional groundwater submodel instead of a conceptual linear storage approach on simulated patterns of soil moisture and water fluxes is analysed.

After validating the model on observed soil moisture and discharge, the effects of the spatial variability of the saturated hydraulic conductivity on hydrological processes and patterns were evaluated in a second step by scenario analyses. As these patterns were established during the construction of the artificial catchment but could not be measured in detail, assumptions concerning the construction have a decisive impact in the simulated patterns of soil moisture and water fluxes. Results indicate that hydrological patterns are significantly influenced by spatially differentiated saturated hydraulic conductivities whereas runoff processes are of minor importance.

Achieving the potential of environmental observatories

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Abstract

Environmental observatories offer the unique potential of combining field data collection sufficient to test specific hypotheses with long-term data collection to monitor a landscape-scale response to variability in climate and other stressors. The success of these field studies in testing hypothesis is well demonstrated. Observatories have provided the kind of data with sufficient intensity spatially and temporally, and with a coherent collection of physical, chemical and biological properties, to permit long-standing views on such fundamental processes as streamflow generation and plant-water interactions to be overturned.

The challenge in operating long-term field sites, however, is in balancing the desire to maintain long-term records – whose value may not be immediately evident – with the need to change data collection strategies to address new scientific challenges. The solution to this dilemma is to place monitoring on more secure scientific footing by having clear hypotheses of what is expected under different environmental conditions. In practice, a clear interpretive strategy for each data series should be in place.

A second challenge for environmental observatories is transferring findings from this site to other similar sites or placing the findings in a broader spatial context. The cost of data collection precludes simply replicating the observatory in multiple locations or at larger scale. Recent technological advances that make sharing data among observatories and with larger scale monitoring networks offers hope that progress can be made through cross-site comparison and the use of monitoring data to generate and at least partially test hypotheses about place and scale.

These two approaches – careful scientific justification of long-term data collection and greater sharing of environmental data to permit its broader use – can help environmental observatories achieve their potential of increasing knowledge and of improving management of land and water resources.

Soil water - storage potential, accessibility and flux as key functions for land use planning at various scales – do we need a paradigm change?

R. Horn

CAU Kiel

Abstract

The Darcian law describes the 1 dimensional water flux under given boundary conditions which have to be fulfilled. Apart from this 1 dimensionality, also the laminar flow, inert properties, and complete pore rigidity are requested in order to obtain validated results. Thus, these restrictions limit the applicability of the Darcian Law mostly to coarse textured or coarse sandy soils (if no turbulent flow occurs), while silty, loamy, and clayey textured substrates mostly would not fulfill these boundary conditions. Most current approaches for calculating water flow are based on a mass balance equation and Darcy's law. Looking in detailed properties of unsaturated soils from the micro- to the macroscale, the restrictions to the maximum preshrinkage and the precompression stress history do not only define the aggregate properties (as the microscale effect) but also the meso – and even the macroscale effect up to the landscape modeling which indeed can alter the modeled outcome so intensely that even the applicability of such models may be questioned. We therefore have to redefine the boundary conditions depending on the site specific properties at all scales.

Sediment formation and initial phosphorus mobilization in an artificial experimental pond: Chicken Creek, E Germany

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Introduction

Many approaches in limnology aimed to find general factors regulating and explaining how lakes develop and why lakes differ in fundamental properties. Particularly, catchment area features, the size and form of lakes regulate general transport processes (e.g. erosion, sedimentation, and resuspension), which in turn govern many abiotic state variables (e.g. phosphorus (P), water chemistry and clarity), regulating its production. An ideal site for those studies is a small pond within the artificially established water catchment area 'Chicken Creek' (Gerwin et al. 2009). The aim of our contribution is to present first sediment core stratigraphies and process measurements at the sediment water interface to document the pond's actual state at point 'zero' and sedimentary P mobilization.

Methods

Chicken Creek pond is located in the Lower Lusatian Mining area, E Germany, at the opencast pit area Welzow-South (N 51° 37'; E 014° 18') about 20 km south of the city Cottbus. This pond was man-made in 2005, filled by natural surface runoff until January 2006. At a mean water level the pond has an area of 3,805 m^2, a volume of 3,992 m^3, and a maximum depth of 2.4 m. The pond was observed in summer 2006 and 2008 to study the matter exchange at the sediment water interface using limnological standard methods (for details see Kleeberg et al. 2010a).

Results & discussion

Within only three years the bottom of pond was covered by a layer of sediment between 0.05 and 0.67 m at water depths >2 m originating from an initially massive surface erosion in the artificial catchment. The sediment thickness averaged to 0.3 m. The maximum sediment depth corresponds to a high sediment accretion (Table 1). Thus, already 19.7% of the original pond volume (6,483 m^3) are filled by silt material with a low organic matter and P proportion which is also reflected in a low P sorption capacity if compared to other lakes (Table 1).

The actual sediment volume corresponds to 1,280 m^3. At a dry weight proportion of 56% and a mean density of 1.91 g cm^{-3} 2,445 kg sediment were accumulated. This mass in turn, provided that it was equally imported from the total area of the catchment area over the three years, corresponds to a mean erosion rate of 13.9 kg m-2 a^{-1} (Kleeberg et al. 2010b).

Rates of matter exchange at the sediment water interface such as oxygen consumption, sulphate reduction and release of soluble reactive P (SRP) and ammonium are rather low if compared to those of 'developed' shallow lakes (Table 1). These results indicate a currently low P mobility where P is mostly bound to metals also imported from the catchment (for further details see Kleeberg et al. 2010b).

Table 1. Determined parameter and rates of surface sediment (0-5 cm) of Chicken Creek pond studied at an initial stage of development in comparison to those of sediments of comparable 'developed' polymictic eutrophic shallow lakes; (FW – fresh weight).

Parameter and rate	**unit**	**pond studied**	**shallow lakes**
Sediment accretion	(mm a^{-1})	200	0.4 – 1.8
Organic matter	(% FW)	4-5	20 – 30
Total P	(mg g^{-1})	0.6-1.0	0.51 – 3.62
P sorption capacity	(mg g^{-1})	0.97-2.59	1.04 – 9.52
O_2 consumption	(mg m^{-2} d^{-1})	549.0	0.3 … 4,000
Sulphate reduction	(mg m^{-2} d^{-1})	91.8	5 – 1,600
Release rate SRP	(mg m^{-2} d^{-1})	0.06	1.6 – 125
NH_4^+	(mg m^{-2} d^{-1})	0.7	270 … 2,200

Conclusions

The actual sediment accumulation and rates of matter exchange in Chicken Creek pond at an initial state of development show clearly, that still soil properties determine the chemical sediment quality and low reactivity. Comparing these characteristics with those of nutrient-burden shallow lakes shows that the sedimentary P mobilization is currently dominated by P accumulation. However, the results presented also suggest that an increasing import of organic matter both from terrestrial and aquatic vegetation could increasingly contribute to the accumulation of carbon stimulating microbial and redox processes. This manner initiating a shift from a geochemical to a biogeochemical sediment diagenesis stimulating the sedimentary P mobilization and translocation to other biota.

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Impact of substrate and microsite conditions on seedling establishment of two Populus species

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Abstract

Exposed mineral soil has been recognized as a favorable substrate for seed germination and seedling establishment of many early successional species. However, there have been relatively few studies investigating the specific soil conditions for the germination and establishment of trees from seed in areas where the natural structure and layering of soils has been lost due to severe disturbances such as open pit mining. As a result the conditions necessary for the establishment of early successional tree species from seed has received little attention in forest land reclamation. In the boreal forest region, aspen (Populus tremuloides Michx.) and balsam poplar (P. balsamifera L.) are two early successional species that are well known for their potential to regenerate vegetatively from their existing root systems. However, both species produce large quantities of light seed that is easily wind-dispersed over long distances. In this presentation we will present data from several studies to shed light on seed bed requirements for the establishment of aspen and balsam poplar seedlings on newly disturbed sites.

In a field study we assessed natural seedling regeneration and microsites preferences in newly disturbed sites which had no aspen prior to disturbance. In order to interpret the field results and gain a better understanding of the mechanisms involved in the tree seedling establishment, we tested in controlled growth chamber studies the impact of different substrate types, based on the natural Ae, Bm and Bt horizons of a Brunisolic Gray Luvisol soil, on germination and establishment success of both aspen and balsam poplar. In addition, we also explored the impact of soil compaction and soil moisture on initial seedling performance.

In the field study we found that the surface soil substrate and its microtopograhy played a significant role in the establishment success of seedlings. Slight concave microsites were preferred locations for seedling establishment, while deep depressions and convex features where not. Aspen seedlings established mostly where the organic and/or upper surface mineral soil layer was mechanically disturbed. In contrast, balsam poplar seedlings were able to establish and grow well even in severely disturbed areas with only the lower soil horizons retained. In the controlled experimental studies we found that balsam poplar grew similarly in all soil horizons and generally had faster radicle growth and leaf area development than aspen and balsam poplar. Aspen, however, only grew well in the Ae horizon, but on this horizon, it outgrew balsam poplar. Aspen's growth in the Ae horizon was associated with higher phosphorus and organic carbon content relative to the lower horizons. The wider range of conditions for successful establishment of balsam poplar can be attributed to its faster root development due to its larger seed size and greater reserves.

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Methane oxidation in Sphagnum during mire primary succession

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Introduction

Primary succession occurs in land that is newly exposed from under water or ice. Since almost all land in the Northern Hemisphere was covered by ice during the last glacial period, most northern ecosystems have gone through primary succession. Some coastal pristine mires are among those few ecosystems where primary succession has continued without human disturbance, and they can serve as model ecosystems to carbon (C) cycling.

Northern mires have a dual role in the C cycling with the atmosphere. Mires are long-term C sinks but important sources of methane (CH_4) to the atmosphere. Methane emission from mires is the sum of production and consumption. Methane oxidizing bacteria are the only organisms that can consume CH_4. They consume CH_4 derived from decaying plants and produce carbon dioxide (CO_2). Recently it was shown that these bacteria may inhabit Sphagnum peat mosses (Raghoebarsing et al. 2005). The mosses in turn fix the produced CO_2 in photosynthesis. Therefore, C released in decomposition would be efficiently recycled within the ecosystem and the moss layer reduced greenhouse gas emissions to the atmosphere. Over half of peat in the world originates from Sphagnum (Clymo and Hayward 1982). Knowledge on ecological strategies of these primary peat producers is essential for understanding constraints of C sequestration and for predicting the role of mires in global C budget under changing climate.

Our study site is a primary successional series of mire ecosystems in the land-uplift coast of Gulf of Bothnia (Siikajoki, Finland (64°45'N, 24°42'E). It consists of seven mires from coast line to inland, the ages of which vary from few years to 3000 years, and the types from exposed sea bottom and meadow like early fens to bog (Merilä et al. 2006). This site offers an exceptional opportunity to study Sphagnum with methanotrophic activity over undisturbed successional gradient.

Our aim was 1) to examine spatial and seasonal variation in methanotrophic activity during the mire primary succession and 2) to determine if the major control for oxidation is the environment or the moss species characteristic to different successional stage.

Methods

Regulation of CH_4 oxidation in Sphagnum was studied in natural moss communities in all the sites. We collected the dominant Sphagnum species from hummock, lawn and flark habitats in each successional stage and determined the potential in mosses to oxidize CH_4 using flask incubations and gas chromatography. Sphagnum species were also transplanted reciprocally over the age gradient to separate the effect of different host species from abiotic factors on CH_4 oxidation.

Results and Discussion

We found that the Sphagnum species showed methanotrophic activity in all the successional stages. All sites showed similar response to water level, which was more important than species differences.

After three weeks, the methanotrophic activity of the transplants did not significantly differ from the native surrounding species. Furthermore, we found that the ranges for CH_4 oxidation rates in ombrotrophic bog and minerotrophic fen mosses overlapped (see also Larmola et al. in press). One reason for this could be that a high N requirement of methanotrophic bacteria could have been compensated for by their N_2 fixation and hence the low inorganic N concentration in the bog sites did not necessarily lead to N limitation and reduced CH_4 oxidation. Supportingly, Opelt et al. 2007 detected that Sphagnum mosses are home to a high diversity of N_2-fixing bacteria. Analyses of active methanotrophic communities in Sphagnum at Siikajoki mires are in progress.

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The sediment redistribution feedback and its role in the initial development of heterogeneously vegetated aquatic ecosystems

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Abstract

The degree of vegetation heterogeneity and spatial arrangement of that heterogeneity are key variables in landscape ecology, influencing overall species richness, competitive and mutualistic interactions, population genetics, response to disturbance, and migration patterns. Whether a nascent ecosystem evolves toward a homogeneous or heterogeneous state depends on a variety of biotic and abiotic factors, including competition for light and limiting nutrient resources, the distribution of disturbance agents such as erosive flows, the distribution of soil elevations and thicknesses, and vegetation life-history strategies. In aquatic ecosystems, it has long been recognized that flow and sediment transport have a dominant influence on vegetation colonization, distribution, and succession. Only recently has the bi-directional nature of flow-vegetation-sediment interactions been fully recognized, with the development of the "fluvial biogeomorphic succession concept" (Corenblit et al., 2007). The concept describes the succession of fluvial landforms and vegetation in response to feedback that, over time, causes a shift in the dominance of hydrogeomorphic versus ecological processes. Still, we have only a limited understanding of how this feedback influences vegetation pattern and process over a range of environmental conditions.

In obtaining a mechanistic understanding of the bi-directional feedback between flow and vegetation and its influence on landscape pattern development, both wetlands and arid riverine ecosystems constitute an important end-member along a continuum of the relative dominance of hydrogeomorphic versus ecological processes. Unlike riverine riparian zones, which tend to be dominated by allogenic sediment deposition and frequently experience flows well above the threshold for sediment erosion, wetlands commonly accrete organic sediment autogenically, and peak flow events tend to be characterized by much slower flow velocities. Meanwhile, in arid riverine ecosystems, the time between flood events is long, whereas vegetation processes occur continually. Thus, in both wetlands and arid riverine ecosystems, ecological processes such as vegetation colonization, soil production or stabilization by vegetation, nutrient uptake, and lateral propagation of vegetation can have a stronger influence over the spatial distribution of physical variables (e.g., flow velocities, water depths, nutrient concentrations) and landscape development than in rivers. Because vegetation still responds strongly to these physical variables, positive and negative feedback loops develop, which can ultimately result in regular, self-organized landscape patterning and nonlinear behaviour such as catastrophic shifts between homogenous and heterogeneous landscape states (Rietkerk et al., 2004).

Mechanisms that have been recognized as drivers of regular vegetation patterning in wetlands and drylands include competition for a limiting resource (light, water, nutrients), feedback between soil production rates and water table location, and ponding of water behind high-elevation, low-conductivity hummocks. Because these processes occur over long time scales, numerical models have been essential in understanding how shifts in the relative dominance of these processes produce different vegetation pattern characteristics, soil elevations, and patterns of resource distribution (see Eppinga et al., 2009). However, these mechanisms often cannot explain the emergence of vegetation features

parallel to flow, such as sawgrass ridges in the ridge and slough landscape, Everglades, FL, USA or ridge-form anabranching streams in arid regions such as central Australia. Thus, a “sediment redistribution feedback” was recently proposed to describe the dynamics of these features (Larsen et al., 2007). The feedback describes the set of processes whereby sediment is eroded from sparsely vegetated channels and deposited within densely vegetated patches, which expand further through biological processes. Initially, deposition contributes to the elongation, and then to the widening, of vegetation patches. However, the high resistance of the vegetation patches to flows eventually redistributes higher flow velocities to the sparsely vegetated channels and ridge margins, until erosion processes at the margins are sufficient to balance expansion processes, leading to a stable landscape (Larsen and Harvey, in press).

Because the sediment redistribution feedback is highly sensitive to subtle spatial variations in flow velocities, vegetative flow resistance, and bed shear stresses, modelling tools to simulate its effect in different environments have not been available until recently. However, recent advances in computing speed, numerical modelling techniques, and the theory of flow through vegetation (e.g., Harvey et al., 2009) enabled us to formulate a simplified yet physically realistic cellular automata model of the sediment redistribution feedback, together with peat accretion, vegetation colonization and spreading processes, and nutrient uptake (Larsen and Harvey, 2010). Because of the model’s efficiency, we were able to perform a general sensitivity analysis over a range of 10 different environmental parameters that encompasses many low-gradient vegetated aquatic floodplains and wetlands worldwide. The design of the sensitivity analysis allowed us to examine how the sediment redistribution feedback interacted with ecological processes to influence vegetation pattern development across a continuum of relative dominance of hydrogeomorphic versus ecological processes.

Starting from an initial state with relatively deep water and little coverage of emergent vegetation, the simulated feedbacks produced a diverse array of patterned landscapes, similar to many types of patterned wetlands found worldwide (Fig. 1). Regular, anisotropically patterned landscapes typically arose only when allogenic processes were strong, characterized by high flow velocities, relatively long flow pulse durations, and relatively deep water. In all of these landcapes, sediment was redistributed from the outside edge of vegetation patches with low resistance to flow to the outside edge of patches with high resistance to flow. The orientation of patches depended on the spatial variability of erosion within low-resistance patches and on the dominant mode of patch expansion. When the erodible sediment supply was low and high-flow durations long, low-resistance patches eroded evenly, maintaining wide low-resistance patches oriented parallel to flow. When the reverse was true, and when macrophyte colonization and growth was rapid, sediment was deposited further to the outside around high-resistance patches and rapidly colonized by plants, which imposed topographic steering of the flow field in a way that reinforced the development of patterning perpendicular to flow.

Initial conditions and processes occurring at early stages of landscape evolution had important influences on the subsequent development of landscape structure as a result of the feedback between flow, vegetation, and sediment transport. The rate of vegetation growth and organic matter production relative to the rate of erosion established the number and location of nascent high-resistance patches that became permanently established at early stages of landscape development, which controlled the fundamental wavelength of the landscape and even the orientation of high-resistance patches. Once patches began to develop a particular orientation, that orientation was reinforced through their

topographic steering effect on flow. Several thresholds also characterized the early development of heterogeneous wetland landscapes. One threshold occurred when high-resistance patches crossed an elevation threshold, at which point the survival of the vegetation community was ensured and the community began to accrete sediment rapidly through dominantly autogenic processes. At a later threshold, a critical mass of high-resistance patches became established.

Fig. 1. Diversity of model outcomes and comparison to actual wetlands worldwide. Images are planform views of the landscape, with white patches representing vegetation with high resistance to flow and black patches representing vegetation with little resistance to flow. Adapted from Larsen and Harvey, 2010.

Their collective effect on the flow field caused bed shear stresses within the low-resistance patches to exceed the threshold for sediment entrainment over a large area, and high-resistance patches grew rapidly due to sediment deposition. Thresholds and nonlinear behaviour also characterized landscape development at later stages of their evolution or in systems with a larger initial coverage of high-resistance vegetation that was newly exposed to flow pulses. Once a critical density of deeper zones formed in the low-resistance vegetation patches, these preferential-flow channels captured an increasingly large proportion of the wetland's discharge, causing rapid colonization of high-resistance vegetation elsewhere and increasing homogenization of vegetation communities. Once high-resistance vegetation communities spread, their coverage could not be reduced by erosion over the range of typical wetland flows examined, as their high vegetative drag depressed bed shear stresses below the critical threshold for sediment entrainment. Rather, only increases in water level that submerged high-resistance vegetation on lower portions of the patch transitions could reduce its coverage. Thus, landscapes governed by the sediment redistribution feedback exhibited hysteresis. Stable, regularly patterned landscapes that developed from a wet initial condition at a particular landscape-forming flow but then diverged to a more homogeneous state after an extended period of lower flows would not return to the patterned condition after restoration of the original discharge. Such

hysteresis in landscape evolution trajectories poses challenge for restoration projects such as the high-profile restoration of the Florida Everglades (Larsen and Harvey, in press).

Remarkable similarity between the morphology of heterogeneously patterned wetland and dryland ecosystems governed by the sediment redistribution feedbacks reflects the common set of dominant processes driving landscape evolution in these systems. However, our modelling shows that the sediment redistribution feedback can also produce landscape patterns (e.g., strings and flarks aligned perpendicular to flow) that are known to arise under other mechanisms as well (Eppinga et al., 2009). Using landscape pattern as a diagnostic tool to understand the processes controlling an ecosystem's evolution would be an important step in generalizing our science and predicting the response of poorly studied ecosystems to climate and land use change. An important remaining challenge is to identify a robust set of metrics (e.g., patch size distribution statistics, length-to-width ratios, topography of patch transitions) that discriminate between underlying mechanisms controlling vegetation pattern development. Community testing and synthesis of modelling results such as those presented here and in Eppinga et al. (2009) is one potential way to address this challenge.

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Pioneer bacterial communities in alpine glacier forefields: local adaptation and stability in a challenging environment

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Glacier forefield communities

The forefields of retreating glaciers represent a unique opportunity to study the role of microbial communities in the early stages of ecosystem development, as deglaciation leads to exposure of bare rock which is rapidly colonized by microorganisms. It is remarkable that such environments consist generally of heterogeneous coarse rock fragments and are void of plants. Moreover, as high-altitude environments, they are subject to extreme climatic variations, on both a daily and a seasonal scale. Winters are characterized by a heavy snow cover, while wet-dry periods alternate from spring to autumn.

The presence and activity of microbial communities which are well adapted to the extreme conditions of these environments is therefore crucial for the biogeochemical cycling of nutrients. These processes open the way to the subsequent establishment of plant species and to the development of more complex food webs. It is now widely recognized that glacier forefields are able to harbour a great structural and functional microbial diversity. For example, several studies demonstrated the importance of Cyanobacteria in glacier forefields and subglacial sediments (Kàstovskà et al., 2007, Duc et al., 2009). Cyanobacteria are able to survive in limiting environments by fixing C and N from the atmosphere. In addition, recent studies also pointed out the importance of heterotrophic microorganisms potentially able to assimilate the limiting C deriving from deposition or ancient C sources (Bardgett et al, 2005).

Despite the characterization of microbial communities in glacier forefields is gaining increasing interest (Sigler & Zeyer, 2002, Nemergut et al., 2007), the link between community composition, activity and the surrounding environment remains to be elucidated. In particular, in unvegetated glacier forefields microbial communities are in close contact with the surrounding physico-chemical environment. An array of environmental factors related to soil properties (pH, nutrients), to the nature of the bedrock (elemental composition, texture, water retention) and to climatic and geographic conditions (exposure, hours of sun, precipitation) may play a role in shaping community structure and determining community function. While certain factors related to the nature of the bedrock are stable in time, soil nutrient status and climatic conditions fluctuate cyclically and may cause additional disturbances to the microbial communities and to their activities. It is still not clear if and to what extent the young communities display stability (resistance and resilience) and are able to adapt to certain environmental changes.

The objective of our study was to analyze the relationships between microbial community structure, activity, and the surrounding environment using glacier forefields as a model system for primary ecological succession. We adopted a multi-disciplinary approach which combines the molecular profiling of bacterial communities and of their activities, with physical, chemical and climatic characterization of the sites.

In a first survey, we compared the bacterial community structure of 6 sites (soil age < 10y) at the front of receding glaciers representing two main lithological types found on the Swiss territory: calcareous

and siliceous bedrock (Lazzaro et al., 2009). Bacterial diversity was investigated using T-RFLP analysis of the 16S rRNA gene (Fig. 1). The influence of several external (eg. rainfall, temperature, WHC) and intrinsic soil properties (eg. soil pH, TC, TN, DOC) on the bacterial community structure was assessed with Canonical Correspondence Analysis (CCA). In this work, we showed that the general structural pattern of the bacterial communities is similar among diverse glacier forefields; it involves an ecological dominance of few taxonomic units which appear in all the sites sampled; however, the nature of the bedrock (siliceous vs calcareous) appeared to determine the additional presence of certain characteristic taxonomic units which may suggest the presence of locally adapted groups.

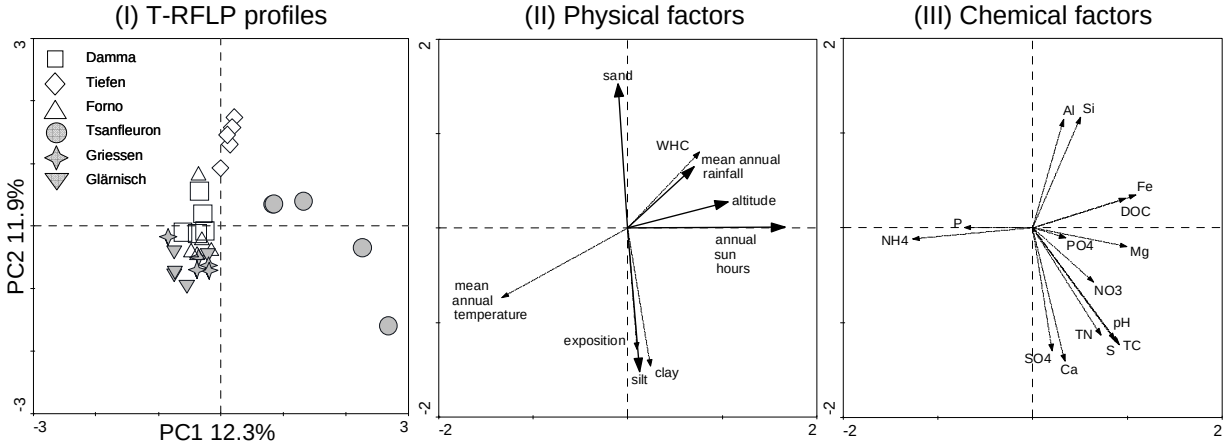

Fig. 1 Ordination plots of canonical correspondence analysis (CCA). (I) distribution of T-RFLP profiles from each soil in relation to physical and soil chemical factors. For each soil, n=5. Bold arrows indicate significantly correlated factors. For clarity of presentation, the scales of (II) and (III) have been reduced. Adapted from Lazzaro et al., 2009.

In a successive study, we further defined the relationships occurring between microbial community structure and activity and different seasons at a reference site (Lazzaro & Zeyer, in preparation). This study involved T-RFLP profiling of 16S rRNA gene, as well as enzymatic analysis and the construction of cDNA clone libraries to identify the dominant active organisms at each season. Sampling was performed in late winter (May) under the snow, after snowmelt (July) and at the end of the summer season (September). 16S rRNA gene-based CCA showed distinct microbial community structures in different sampling periods, suggesting seasonal shifts in the microbial communities (Fig. 2).

Seasonal patterns were observable also in the nutrient status and in some of the enzymes assayed. However, cDNA-based clone libraries showed that at all seasons the dominant active bacterial members belonged to the class of α-Proteobacteria. These results indicate that although α-Proteobacteria may represent a relatively stable group in the glacier forefields, the seasonal climatic fluctuations influence greatly the nutrient status of the soil and in turn affect the overall microbial activity. Further studies are needed to assess the ecological stability of the microbial glacier forefield communites towards extreme environmental changes.

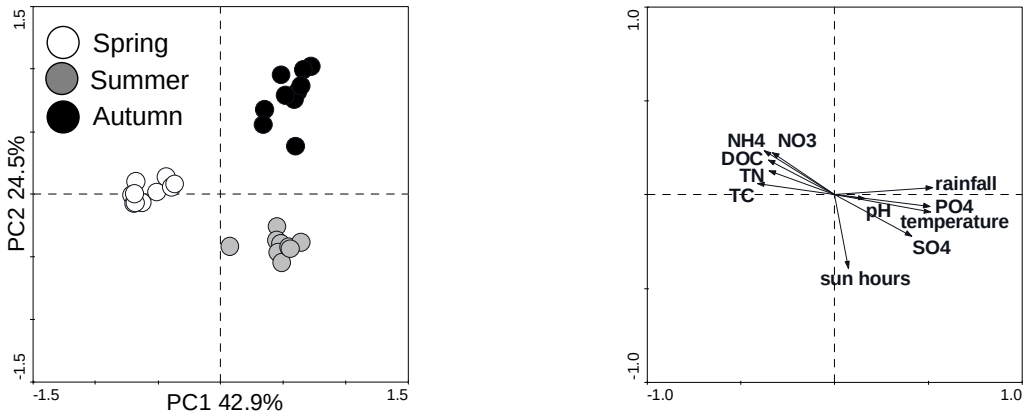

Fig. 2. CCA analysis of T-RFLP profiles of the Damma glacier forefield (reference site). For clarity, the CCA plots have been split into T-RFLP profiles (n=10) and environmental factors. Adapted from Lazzaro & Zeyer, in preparation.

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Local-scale distribution of organic matter composition and wettability at surfaces of preferential flow paths

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Abstract

Surfaces of preferential flow paths in structured soils consist of clay-organic coatings (i.e., cutanes) on soil aggregates or linings on biopores (i.e., worm burrows and decayed root channels). The outermost layer of such surfaces is mostly covered by organic matter (OM). The composition of this OM finally controls wettability and sorption properties that are relevant for transport along the flow path. However, the local distribution of OM-properties along such surfaces is largely unknown because analyzes without disturbing the coating layer surfaces have not been possible to date.

The objective of this study is to compare the local 2D distribution of soil OM composition at intact aggregate and biopore surfaces with that of the wettability. The OM composition is determined using Fourier transformed infrared spectroscopy in diffuse reflectance mode (DRIFT) in terms of the ratios of CH/CO functional molecular groups. Intact surfaces of aggregated soil samples were scanned using a DRIFT mapping procedure in a 1 mm grid. Wettability was observed by means of contact angle measurements using a Goniometer with a high-speed camera. The aggregate sample surfaces were distinguished into regions of earthworm burrows, root channels, clay-organic coatings and uncoated regions. In contrast to the uncoated surface areas, organic coatings on worm burrows and root channels show relatively higher CH/CO-ratios that correspond with longer water drop infiltration. Both, the OM composition of coatings along preferential flow path surfaces and the water repellence are spatially variable at this local scale. The results indicate yet unknown implications for preferential flow and transport especially for reactive solutes.

Colonization pattern and photosynthetic activity of pelagic and benthic autotrophs in a pond (Hühnerwasserteich) in the initial stage

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Abstract

The investigation of the limnological development of a newly formed pond ecosystem on a mine site in the Lusatian mining district offers the opportunity to analyse the succession of primary production by phytoplankton and macrophytes with regard to key organisms and processes for pond development against the background of the rapidly changing environmental conditions. Hühnerwasserteich is part of the central investigation site of the Transregional Collaborative Research Centre (SFB/TRR) 38. The pond has a current volume of about 4,000 m³ and an area of about 0.4 ha. Maximum depth is about 2 m. Its artificial catchment was built in spring 2005 after open-cast lignite mining in the area. The water of the pond can be characterized as a calcium-sulphate-hydrogencarbonate water with nutrient concentrations in the mesotrophic range.During the initial stage, autotrophic inhabitation of Hühnerwasserteich was characterized by a high variation in the phytoplankton community without a seasonal pattern. Since 2008 macrophytes occurred in addition to phytoplankton and phytobenthos and reached a primary production that was 4 to 10 times higher than that of the phytoplankton. In summer 2009, already a diverse coenosis of aquatic macrophytes occurred and covered major parts of the benthal. From March to August 2009, primary production of macrophytes showed a similar development as the production of the phytoplankton, but the intensity was 4 to 10 times higher. The maximum of area specific macrophyte and phytoplankton production was in July. Specific macrophyte production was high at the beginning of macrophyte growth and reached its maximum in June. Bacterial production was relatively constant and was slightly higher than phytoplankton primary production.

How many degrees of freedom does a catchment have?

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Abstract

Catchments are often considered to be complex systems. Hydrological and hydrochemical processes are characterized by substantial spatial hetereogeneities, nonlinearities, and interdependencies at different scales that interfere with model-based predictions. In contrast, some studies gave evidence that the number of degrees of freedom, that is, the number of independent processes that exert an influence at a given scale, is very limited. It seems that catchments are in fact subject to many more constraints compared with what our theories and models postulate. This could be due, e.g., to a multitude of negative feedback loops. Consequently, certain phenomena are very rarely observed although they could be easily modelled.

In this paper, different approaches will be given how to assess the degrees of freedom of catchments based on analysis of catchment behaviour, e.g., hydrological time series or spatial patterns of water quality. To that end, nonlinearities and scale dependencies need to be accounted for. In addition, much of a catchment's behaviour can be traced back to a damped and delayed response to input signals. The degree of damping can be measured, and this information can be used for optimizing hydrological models and water resources management even in data-sparse environments. These approaches help considerably to differentiate, e.g., between natural heterogeneities, climate change effects, and anthropogenic impacts even in apparently complex systems where groundwater and surface water bodies interact. In fact, the results confirm the basic assumption that the number of degrees of freedom of catchment behaviour often is very limited and catchment behaviour is much less erratic than often assumed.

Reproducing the initial internal structural heterogeneity of an artificially created catchment

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Abstract

During the pioneering phase of catchments, the initial spatial distribution of structural features like sediment texture and bulk densities determines the structural dynamics to a great extent. During this time, the specific internal structuring governs both superficial and subsurface processes. Realistic information on the internal structural framework and the 3D spatial distribution of sediment properties is thus vital for the correct interpretation of observed structural dynamics.

The objective of this study was the reconstruction of initial internal structural features, exemplified for a small artificial hydrological catchment. The study was carried out for the artificially created catchment “Chicken Creek” near Cottbus, Germany, where mining spreader technology generated a characteristic sediment structure.

Digital Elevation Models (DEMs) derived from photogrammetric surveys during construction and after completion of the catchment were used for the construction of the delimiting surfaces and the estimation of volumes and masses. In the following step, a 3D-volume body (SGrid) was created with the 3D modelling software GOCAD. With a structure generator, 2D digital representations of spoil cones as the basic structural elements were generated. The structure generator incorporates specific bulk density distributions depending on drop height and angle, as well as textural and mineralogical differentiation due to segregation processes. The scientific background of the program is based on theoretical assumptions and experimental field studies of soil cone profiles. Textural and mineralogical information of the outcrop side are used. The 2D cross sections are distributed along the spreader course. Imported into the GOCAD SGrid as property values, the structures were verified by comparisons with on-site soil profiles and bore hole information and results from non-invasive geophysical investigations.

The 3D catchment model with internal structure will serve as a basis for deriving the 3D-distributions of hydraulic properties for hydrological modelling and may help to better understand processes of the pioneering phase.

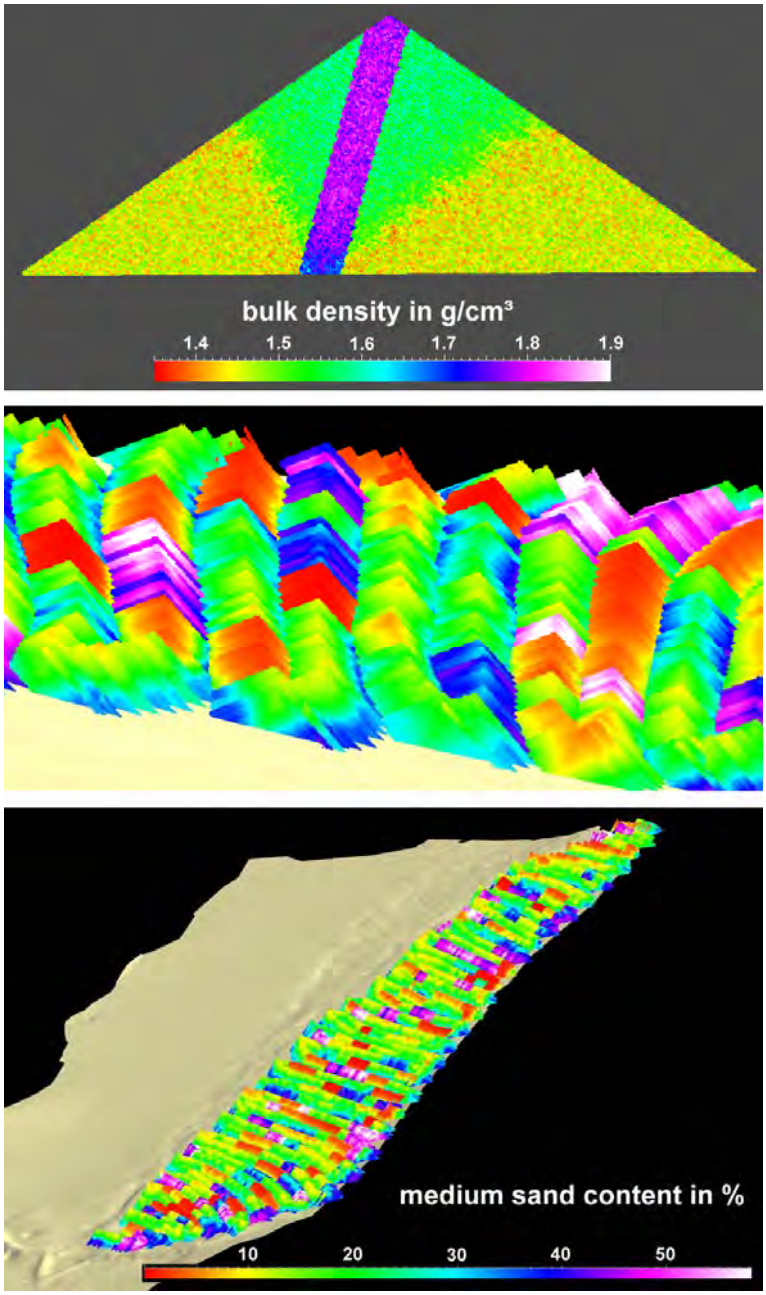

Figure 1: Virtual spoil cones and ridges, generated with the structur generator program and visualized in GOCAD.

The changing artificial catchment “Chicken Creek” – catchment structures and hydrological processes

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Abstract

Two main challenges hamper progress in catchment hydrology: (i) the open dynamic character and (ii) the unique development of each single catchment. The artificially created hydrological catchment “Chicken Creek” provides well defined boundary conditions, and a dense observation net to study structure or process changes due to catchment development. The ongoing research aims at the identification, analyses and potentially at the generalisation of crucial interactions between hydrological processes and structures as well as thresholds for changes in catchment behaviour.

Owing to the development of the catchment, the contrived multi-response observation net was established in a way that enables prompt and flexible observations of structural changes. Thereby, a time-dependent analysis of the temporal runoff behaviour and of the several runoff components is possible.Anyway, even in an artificial catchment as the presented one and despite of the well defined catchment boundaries, the uncertainties are pretty large. It concerns particularly the crucial parameters evapotranspiration and subsurface water storage. The uncertainty of these components impedes the closure of the water balance.

By the established groundwater flow model, the relevance of natural or artificial structures on the runoff separation process is analysed. The model supports the interpretation of observations but also the iterative evaluation of information need for system understanding. The importance to consider groundwater and surface water interactions is reflected as well as the unexpected long period prior an establishment of dynamic equilibrium conditions in the aquifer.By the visual observations and analyses of measurements, but also by the groundwater flow model, the precipitation induced surface runoff was identified as the quantitatively dominating hydrological process in the initial phase of catchment development. The originally more the less plain catchment surface was significantly structured by the formation of runoff relevant erosion structures which show up to be important for the biotic development processes.

The research proves the hypothesis that initially existing and evolving structures determine the distribution and development of the hydrologically relevant processes but also the development of the catchment as a whole.

Transitions of self-organised vegetation patterns in arid ecosystems induced by variations in topography

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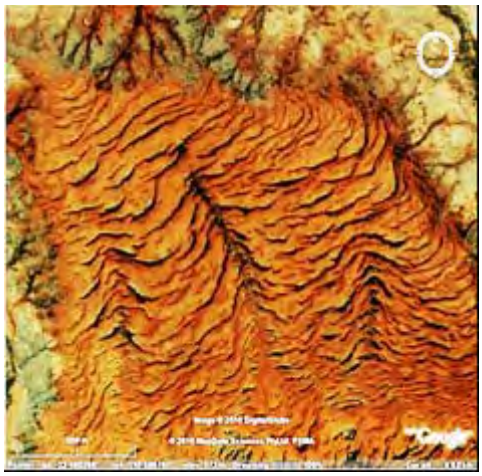
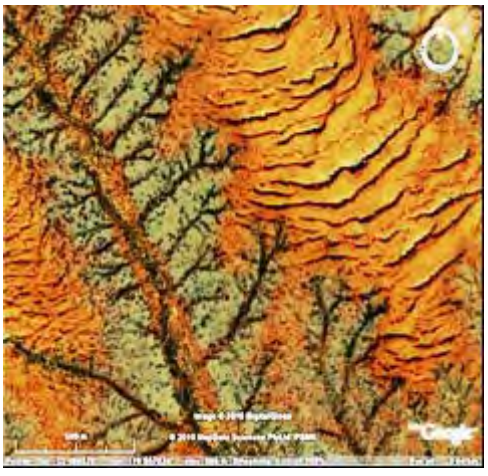
Abstract

In water limited systems the spatial distribution of vegetation self-organises into a mosaic of vegetated patches and bare soil. A mechanism thought responsible is the interplay between long range competition (C) for resources such as water, and short range facilitation (F) of the environment, such as reduced soil evaporation and improved soil structure under and adjacent to plant canopies. When a topographic gradient is present patches can interact with one another via interception of surface runoff, leading to the formation of bands of vegetation on smooth, gently sloping terrain. Competition and facilitation generated vegetation patterns have been extensively studied in association with smooth, flat or gently sloping terrain, but little is known about the self-organisation of vegetation patchiness in more heterogeneous topography. Here we show, with a C-F cellular automata model, that variation in topography, controlling surface water redistribution, can significantly alter self-organised vegetation patterns. We demonstrate that the same model reproduces patterns seen in a banded system subjected to slight flow convergence (Fig. 1a and Fig. 2) as well as the self organisation of vegetation along an ephemeral fluvial network (Fig. 1b and Fig. 3). These results also suggest that sediment transport processes, smoothing the terrain, are essential for the maintenance of banded patterns. Furthermore, the re-organisation of surface water flow pathways following degradation of patchy ecosystems systems may provide a positive feedback exacerbating the degradation process.



(a) 23 29` S, 119 35` E



(b) 23 29` S, 119 33` E

Fig. 1: Satellite images of banded vegetation in the vicinity of Newman, Western Australia, obtained from Google Earth™. The red-brown parts of the each image are bare soil, the grey areas grasses, while the darker parts are predominantly trees. The scale bars in the images are 1800 m and 1100 m respectively.

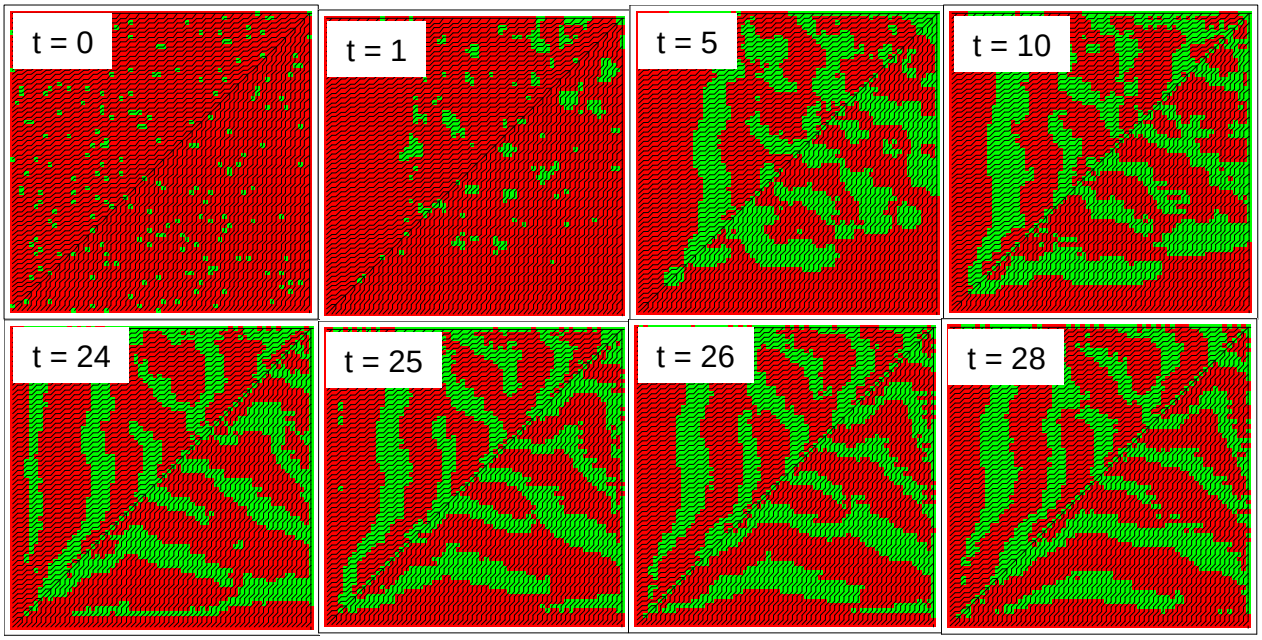


Fig. 2: Band deformation around a drainage line showing vegetation distribution (green) during the initial evolution (0≤ t ≤10), and then the dynamics at maturity (24≤ t ≤28), illustrating band separation, merging, and pinching. Black lines indicate surface water flow paths.

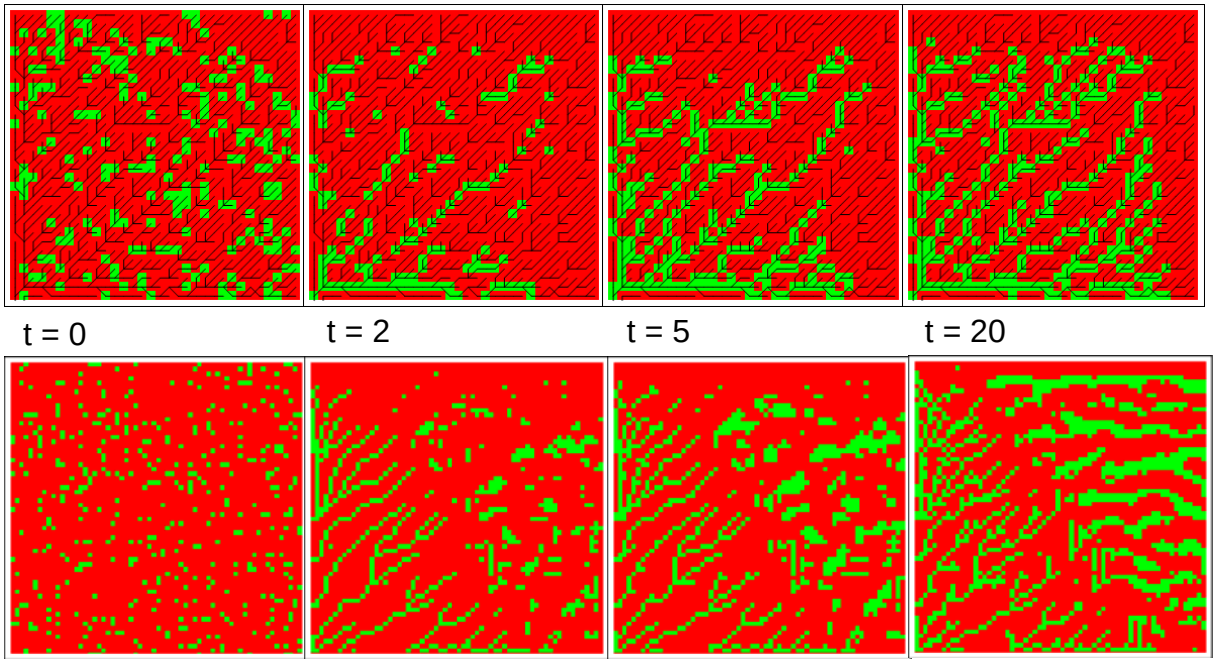


Fig. 3: Self-organisation of vegetation pattern in response to a self-similar network topography (top) as well as the combination of a fluvial network adjacent a gently sloping plateau (bottom).

Soil organic matter quality as a link between microbial community structure and vegetation composition along a successional gradient in a boreal forest

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Abstract

In this study we hypothesized that a change in the composition of vegetation communities is closely linked to a concurrent change in the structure of microbial communities through the decisive role of plant residues in regulating the quality of carbon sources for soil microbes.

The study was carried out in a boreal forest along an 80 m-long successional transect (willow, alder, birch, spruce) located on the land-uplift coast of the Gulf of Bothnia, western Finland. The field and ground layer vegetation were recorded by species percentage cover on 2 m2 sample plots located at 10 m intervals. Organic layer samples were taken from around each vegetation sample plot for the determination of phospholipid fatty acid (PLFA) profiles and chemical composition of the organic layer, as characterized by the concentrations of neutral and acidic sugar units in non-cellulosic polysaccharides, cellulose, the acid-soluble lignin (ASL), and acid-insoluble residue (AIR).

The organic layer along the transect showed a decrease in pH (from 5.2 to 4.4), moisture content and concentrations of ASL and the hemicellulosic sugars arabinose, rhamnose, xylose, galactose, and glucuronic acid, while the AIR concentration increased. These organic matter fractions and pH also showed a strong positive or negative correlation with the vegetation and the PLFA ordination. The percentage cover of grasses significantly correlated with the PLFA data, as well as with that of herbs and field layer species. However, PLFA ordination showed a higher correlation with the organic layer properties than with the coverage of plant species groups.

In conclusion, our data showed a strong directional relationship between the organic matter characteristics and structure of the vegetation and microbial communities along the study transect. This study is, to our knowledge, the first investigation to apply acid methanolysis in the characterization of non-cellulosic polysaccharides in the organic layer.

Looking below ground in natural and artificial ecosystems

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Abstract

Vegetation research, if done in an ecosystem context, must include the soil substrate. The answers to plant behavior and community formation are often found by looking below ground. I will emphasize what I call the “Geo” factor in ecosystem development through a brief review of my past vegetation research. It started on Vancouver Island with the analysis of natural soil catenae. It then continued in SE Manitoba with forest habitat research, which led to the construction of artificial catenae for answering questions of forest tree distribution. My first task in Hawai`i was to investigate soil-vegetation relationships in kipuka. In Sri Lanka, with mycologists, we dug soil pits in patana grassland to elucidate the sudden change from red-soil to black-soil at 5000 feet elevation. The Hawai`i IBP (International Biological Program) in the early 1970s demanded interdisciplinary team research. One project focused on altitudinal ecosystem analysis with 16 organism groups, six of them being soil organisms. In 1975, the native rain forest dieback demanded urgent attention. As part of the dieback research, artificial catenae helped to clarify that pathogens were not the cause. Finally, work with small-scale artificial ecosystems, based on water cultures without soil (hydroponics) in my home garden, led to an appreciation of the soil food web. Unfortunately, this important organismic component was mostly overlooked in my looking below ground. Why? I will explain.

Coastal water quality in the vicinity of a nuclear power plant, southeast coast of India

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Abstract

Natural water bodies are being extensively used as heat sinks by various industries, especially by power plants (Langford, 1990). Thermal effluents released from such plants into the receiving water body - sea or lake, can directly and indirectly affect the ecosystem dynamics of the receiving water body. Through its effects on density, temperature is also involved in advective mixing processes and in turn is a major factor in primary production. Seasonal fluctuations in water temperature distribution play an important role in influencing biological processes (Kinee, 1972). In this context, the environmental effects of thermal discharges from power stations into coastal and inland water bodies have been the focus of research (Dev 2000, Mayhew 2000, Choi 2002) as well as legislation elsewhere in the world. Madras Atomic Power Station in Kalpakkam (80°10'43'E and 12°33'27"N) situated 65km south of Chennai, discharges coolant water with a ΔT of 10°C. Water quality monitoring was carried out in vicinity of the power plant covering a distance of 3km on either side of the discharge point and extending to 1km into the sea from the mixing point. Monthly surface and bottom water samples were collected in transects from a distance of 200m, 500m and 1km from the shore on full moon day and analysed for suspended particulate matter, nutrients, Biological oxygen demand and chlorophyll a. Water temperature, dissolved oxygen concentration, pH, salinity and light penetration depth were measured on site. Finally the coastal water quality around MAPS were compared with reference stations at Sadras (7km south of mixing point) and Mahabalipuram (7km north of mixing point). Temperature at the mixing point during the study period varied between 31°C to 34°C whereas at reference stations it varied between 28°C to 31°C. The nutrient concentration at the mixing point is reduced, which increases gradually. The maximum concentration within the study area is observed at stations 3km from mixing point.

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Monitoring installations at the Chicken Creek catchment

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Abstract

At the Chicken Creek catchment, instruments for the monitoring of several environmental parameters have been installed. The aim was to provide basic data and time series of meteorological, hydrological, ecological and soil conditions. Prior to monitoring samples had been taken on the basis of a regular grid, which proved the Quaternary substrate to be relatively homogenous both horizontally and vertically. Therefore, all installations were initially oriented along this grid. Due to the evolution of structures and patterns within the catchment in the first five years of ecosystem development, these installations were successively complemented to better represent the differentiating site conditions within the catchment.

Microdrone-based aerial monitoring of initial ecosystem development

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Abstract

Aerial photographs were taken for the monitoring of temporal and spatial changes in the course of the highly dynamic development of the artificial Chicken Creek catchment. The images were taken using a microdrone-based tool containing a commercial digital camera. This technique allows easy access to aerial photographs and furthermore a potentially high temporal monitoring resolution. The microdrone-based aerial monitoring enables to detect structural changes at the catchment scale (e.g. development of erosion channels, vegetation dynamics and vegetation cover). Therefore, it is an innovative and cost efficient approach to study small-scale landform evolution.

Estimability analysis of hysteretic soil hydraulic parameters from field irrigation-infiltration-runoff experiment

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Abstract

Soil hydraulic parameters are required for quantitatively analyzing water movement in variably-saturated soil. For field model calibration, these parameters can be obtained by analyzing results of irrigation experiments. However, the effect of hysteresis in the soil water retention function has often been neglected because of a lack of data and methods to determine the complex hysteretic parameters. Inverse estimation methods still have problems with respect to the non-uniqueness of optimized parameters. Estimability analysis performed before parameter calibration may help to identify the most sensitive parameters and to increase efficiency of the optimization procedure.

The objectives of this study were to (i) investigate the estimability of hysteretic hydraulic parameters from the data of a field irrigation experiment and (ii) to optimize the estimable parameters by comparing two scenarios.

The soil and rainfall data are from an irrigation experiment carried out by subproject A4 of the SFB/TRR 38 (S. Bartl et al., 2010) at the BTU Cottbus. A one-dimensional numerical model, HYDRUS-1D, was used to simulate the soil water movement. Estimability analysis was based on sequentially calculating a sensitivity coefficient matrix to classify parameter estimability. The optimization was performed by means of the Levenberg-Marquart method implemented in the HYDRUS software.

The results of the estimability analyses showed that the pressure heads at the soil surface contained more information content for parameter calibration than the one measured greater depth; compared to the drying branch, the wetting branch seems to contain more information content for the optimization of hysteretic hydraulic parameters. The fitting between simulated values and data was slightly improved when the model accounts for the hysteresis phenomenon. The effect of temporal variability of hydraulic parameters of the soil surface layer on the parameter estimability and optimization may further improve the results.

Primary succession in a pond (Hühnerwasserteich): physico-chemical conditions, plankton coenoses and primary production

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Abstract

There are only few studies about limnological primary succession of freshwaters. The fast changes in the general living conditions lead to distinct adaptation reactions of the biocoenosis. Our study deals with the primary succession of a pond ecosystem in the post-mining landscape of Lusatia, Germany. Hühnerwasserteich has formed at the lowest part of a new artificial catchment area since 2005. The pond is part of the central investigation site of the Transregional Collaborative Research Centre (SFB/TRR) 38. The current volume is about 4,000 m³ and the area about 0.4 ha, maximum depth about 2 m. Hydrological conditions and erosion in the catchment area have continuously changed the morphology and the physical and chemical conditions.

While during the first years pond succession was mainly influenced by allochthonous impacts, the third and fourth year showed significant autochthonous processes that governed the pond succession. The phytoplankton and zooplankton coenoses were characterized by the absence of a seasonal pattern of plankton succession during the initial stage. Planktonic primary production was on a mesotrophic level and was limited by phosphorus and silicon. From the third year aquatic macrophytes played a growing role in the ecosystem. Their primary production rate exceeded phytoplankton primary production up to ten times and dominated structure and metabolism of the pond. Bacterial production and net community respiration were relatively high. In total, the system tended to net autotrophy.

Development of non-invasive method for estimating soil water content at intermediate scale using cosmic-ray neutrons

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Abstract

Fast neutrons are generated naturally at the land surface by energetic cosmic rays. These "background" neutrons respond strongly to the presence of water at or near the land surface. Soil moisture, snow, and biomass each have a distinct influence on the spectrum, height profile and directional intensity of neutron fluxes above the ground, suggesting that different sources of water at the land surface can be distinguished with neutron data alone. Nowadays new instruments (Zreda et al., 2008) are available for the detection of this cosmic-ray neutron fluxes (count/hour) and they represent a great prospect for intermediate spatial scale of observation that is ideal for land-surface studies and distributed modeling (e.g. about 600-m diameter area and at vertical scale of decimeters).

Based on this approach, we present the first results collected with these new devices in an experimental site. In parallel to direct measurements of cosmic-ray neutrons, a monitoring network consisting on soil moisture sensors (Theta probes) and soil moisture profile probes (up to 1-m depth) was set up in the field.

Actually, other applications using measurements of cosmic-ray neutrons are being developed in our research group such as monitoring of tree water content in forest, real-time soil moisture cross-sections in long distance, snow water equivalent height, etc. We believe that new hydrological approaches using cosmic-ray neutrons can cover the lack of understanding of hydrological processes at the intermediate scale between point measurements and large scale measurements.

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Effects of physical and mechanical processes on initial ecosystem development

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Abstract

The development of an ecosystem depends on many conditions. Among others, the interaction between soil and water and the effect of soil solifluction due to inclined terrain surfaces play a key role for the evolution of soil structure. Water influences the development of the ecosystem in many ways. One is the destabilization of soil by reduction of its shear strength. In conjunction with the effect of gravity associated with sloping surfaces a fluctuating groundwater table may lead to a down slope mass movement in the artificial water catchment chicken creek.

Soil mechanical measurement and modelling are carried out to study the stability of the recently built chicken creek catchment where glacial sand was deposited above a clay layer with an inclination of about 3,5%. Mechanical and physical properties of the soil are determined by laboratory measurements on undisturbed soil samples taken from the field site. Among the measured parameters were the precompression stress, swelling index, coefficient of compressibility, void ratio and the Young's modulus of elasticity determined by confined compression test (oedometer). Shear parameters were determined by direct shear test after samples were consolidated at various normal stresses for 24h. Based on the determined mechanical parameters finite-element-model (Plaxis) was parameterized in order to simulate soil movement under different hydraulic conditions (levels of water table).

More than 50% of the measured precompression stresses indicated very low soil stability (DVWK, 1995). This means that low pressure can lead to irreversible plastic soil deformation resulting in a change of soil structure in turn influencing the pore size distributions and pore geometries, which finally will affect the hydraulic soil properties. The first finite-element-modelling results, however, show only small mass movement along the slope with lateral distances between a few µm to mm. However, movement close to the lake at the lower part of the catchment is higher than in the upslope area due to the steeper slope at the bottom of the structure. Finite-element-modelling also showed an unequal horizontal movement in different zones of the soil body indicating the development of lateral shear zones, which could result in change of pore shape and orientation leading to anisotropic hydraulic conductivity function.

In the next steps a laboratory experiment with a scale of about 1:130 is being built in order to more systematically study the relationship between hydraulic and mechanical stresses and associated soil mass movements. Such investigations will also serve as a validation of the finite-element-modelling results.

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Spatial correlation of soil properties in the artificial catchment “Chicken Creek” at an early phase of ecosystem development

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Abstract

Biotic and abiotic processes cause characteristic spatial (and temporal) patterns in terrestrial ecosystems. Such patterns often manifest themselves as a scale dependent variation of some state variables of the system. Studying them is one way to learn about processes dominating energy and matter fluxes and interactions between organisms within an ecosystem. One method to investigate spatial patterns is the analysis of variance of data collected in surveys in which the sampled locations are hierarchically nested in space.

We used a nested sampling design to elucidate the spatial scales of variation of chemical and physical soil properties in the 6-ha catchment “Chicken Creek”. This catchment was artificially constructed in the Lusatian lignite mining landscape near Cottbus, Germany, in 2004/2005. The expectation was that soil properties varied without much spatial structure in the newly constructed catchment. Spatial patterns were thought to evolve in the course of ecosystem development as the result of processes such as erosion, formation of preferential drainage paths on the surface and within the soil, non-uniform chemical weathering, uneven colonization by organisms and others.

Topsoil was sampled in 2008 at 192 locations using a balanced nested design on six spatial scales (0.2 to >60 m). The samples were analysed for particle size, organic matter content, pH, soluble P, and various fractions of selected metals. Variance components, associated with the spatial scales of the nested design, were estimated by restricted maximum likelihood. We used likelihood ratio tests and likelihood based confidence regions for inference about the spatial autocorrelation patterns.

Likelihood ratio tests showed that all variables were spatially autocorrelated (Fig. 1), some variables even strongly, but the allocation of the variance to specific spatial scales was highly uncertain. For most variables, at least one variance component could not be precisely identified, because the profile likelihood surface was flat. As 95%-likelihood joint confidence regions for accumulated variance components show, the shape of the variogram is poorly defined for most variables (Fig. 1). For some variables, a variogram with a dominant nugget (increase of semivariance only up to 0.2–0.6 m) was found to be equally consistent with the data as a variogram with an unbounded increase of the variation up to the largest spatial scale (>60 m).

Although the sampling could not be performed at the very beginning of the ecosystem development in 2005, our results suggest that the development of the ecosystem in the “Chicken Creek” catchment did not start from a spatially unstructured soil. For most variables, we found substantial spatial variation — the coefficients of variations ranged from about 15 % to more than 70 % — and strong autocorrelation three years after the construction of the catchment. While the spatial distribution

patterns of some of the analysed variables may have changed during the first three years of ecosystem development (e.g. for organic matter and soluble P content), a substantial change in spatial patterns is rather unlikely for others (e.g. total contents of metals). It is more likely that the observed spatial structures are primarily related to initial heterogeneities deriving from the construction process. However, in spite of the sound evidence for autocorrelation, we could not reliably attribute variance components to specific scales.

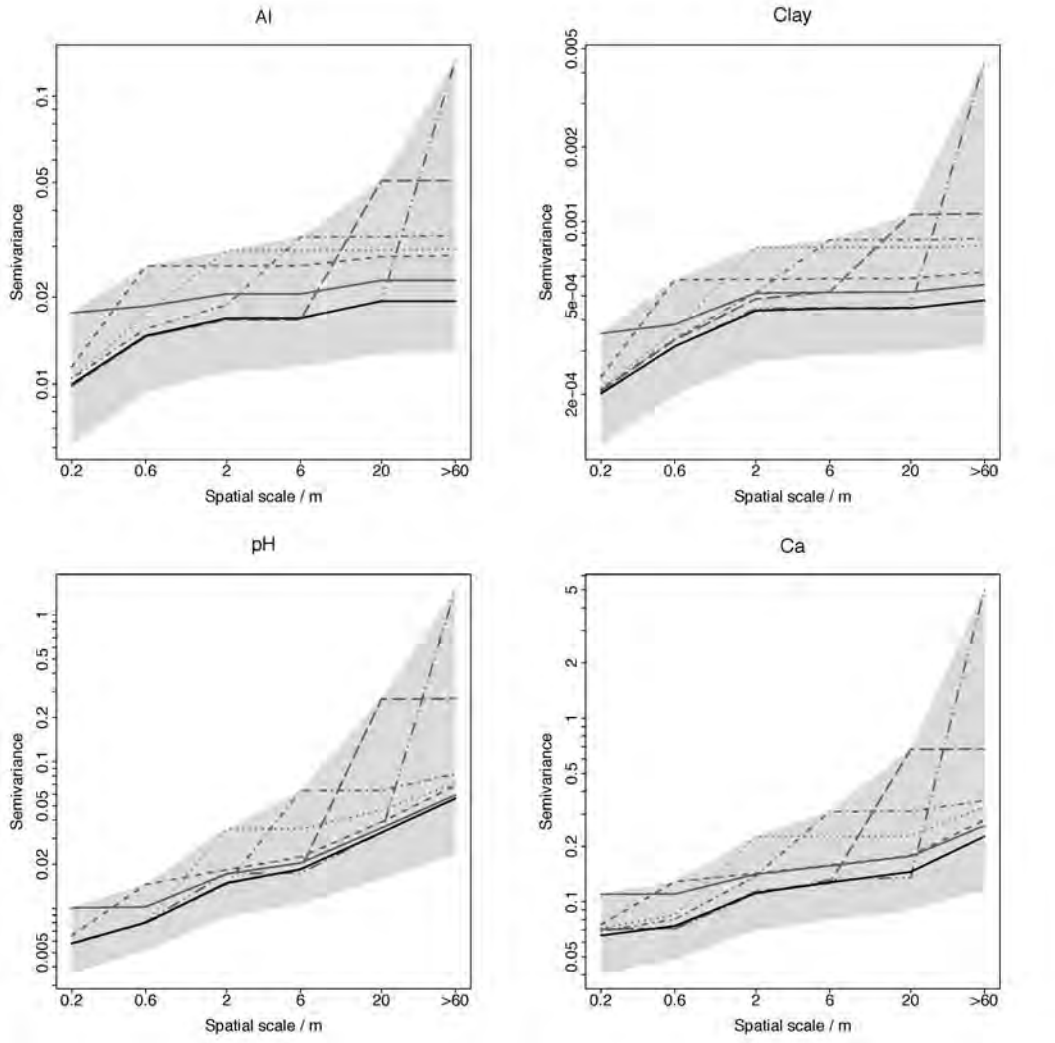

Figure 1: 95 % log-likelihood confidence regions for the accumulated variance components (semivariances) plotted against the spatial scales of the nested design for four variables. The solid black lines are REML estimates; the grey lines show semivariance curves that hit the upper bounds of the confidence regions at the six spatial scales.

Dissecting the surface – stream corridor structure in a newly created landscape

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Abstract

In non-vegetated initial landscapes streams are among the first morphological surface structures to develop. However, the undirected initial development of an entire stream network from a uniform surface and the initial stream corridor structures can seldom be observed. We compared morphological characteristics of three streams in the artificial 'Chicken Creek Catchment' (http://www.tu-cottbus.de/sfb_trr/index.htm) during the third year of its undirected development. The dynamics of the stream bed levels were assessed and related to single precipitation events, while furthermore a comparison was carried out to detect seasonal differences in system behaviour. Overland flow had carved into the uniform surface of the bare landscape and induced the development of an initial dense stream network, which was enhanced by easily erodible sandy soil and a high surface slope in the catchment. The three stream corridors showed a surprisingly variable morphology, including varying catchment sizes, longitudinal- and cross-profiles. Flood events, but also lower discharges, led to locally varying dynamics in the bed level. In the lower part of the catchment, where surface slopes were steeper, streams incised deeply, showed unstable bed slopes, steep to vertical banks, and frequent bank failure. Likewise, abrupt changes in bed level, which indicate ongoing nick-point erosion, highlight the non-maturity of the fluvial structures. While the general route of the major streams seems established, the large variability of cross-sectional parameters and the longitudinal distribution of slopes indicate an unstable situation within the stream corridors. However, first signs of bank and bed form stabilisation by herbaceous vegetation could be detected, and in smallest ephemeral rills the vegetation retains sediments and appears to initiate their transition to a terrestrial soil reducing the stream density in the catchment. Hence, the main reaches of the early stream network in newly created landscapes seem to be long-term pathways of water and sediment controlling the catchment relief.

Can old organic carbon drive microbial activity in surface waters of a newly created landscape?

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Abstract

As in other man-made landscapes and recently deglaciated land surfaces, the substrate of the Chicken Creek Catchment (http://www.tu-cottbus.de/sfb_trr/index.htm) contains high amounts of fossil organic carbon. This old carbon appears to be mobilized in the initial phase of ecosystem development, as indicated by high concentrations of dissolved organic carbon (DOC) in upwelling groundwater. During transport from soils to aquatic ecosystems, both DOC quantity and quality can change as a result of sorption at mineral phases and biogeochemical transformations. In turn DOC bioavailability and microbial community structure would be affected. In a microcosm experiment we assessed whether the quality and bioavailability of DOC differs along the hydrological flow path in the Chicken Creek Catchment from soil solution to stream and pond water. In addition, we compared the potential of microbial communities from soil, stream sediment and pond water to mineralize the DOC sampled. In upwelling groundwater DOC had a mean ^{14}C age of 2600-2800 years, indicating that it was indeed mobilized from old substrate. High concentrations of aromatic compounds and low concentrations of carbohydrates revealed the recalcitrant character of the DOC. This idea was reinforced by low levels of respiration activity in all microcosms containing either soil solution, upwelling groundwater, hyporheic stream water, or pond water. Despite differences among microcosms in the dynamics of respiration during the 72-day incubation period, the microbial communities of soil, stream sediment and pond water revealed similar level of activity. Future analyses will provide deeper insight into the dynamics of DOC components, the associated microbial communities, and the variability of both. Our results suggest that old organic carbon is an important source for DOC exported from newly created catchments. Due to its low bioavailability, the old DOC, however, is less significant for the microbial activity in new landscapes.

Investigation of initial soil food webs - composition and trophic structure

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Abstract

The development of initial soil food webs is one of the first important stages in the process of primary succession and recultivation of a post mining area (Fig. 1). Especially the organisms of micro- and mesofauna – such as nematodes, tardigrades, springtails and mites are the first components of early soil food webs and play an important role to initialize the nutrient cycle. Little is, however, known about the key factors that affect the initial food web composition and the trophic interactions within the system.

Initial soil food webs in a post mining area in Lower Lusatia are studied, where five different treatments had been applied: natural vegetation, sowing of *Lotus corniculatus*, litter of *L. corniculatus* and of *Calamagrostis epigejos* and control (without vegetation). Soil samples were taken 6, 11, 18 and 49 weeks after treatment. Micro- and mesofauna were extracted according to Baermann and MacFadyen; nematodes, tardigrades, springtails and mites were counted; nematodes were determined and assigned to feeding groups. Other components and parameters of the soil food web have been assessed quantitatively (e.g., nematode biomass). First results reveal the complex trophic structure of these initial soil food webs.

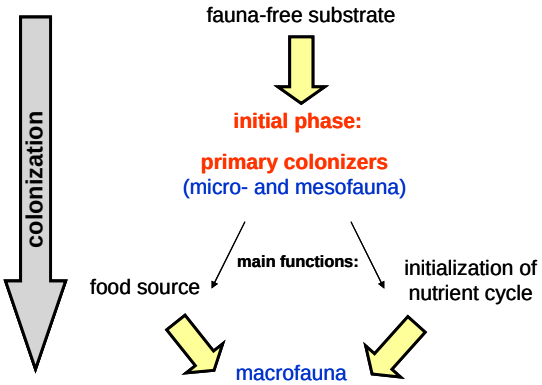

Fig. 1: Simplified overview about the first steps of primary succession

Quantifying mechanisms of aquifer salinization at the Alto Piura Valley, northern part of Peru

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Abstract

The Alto Piura aquifer (Peruvian northern coastal area) supports the important agricultural activity in the region and provides water supply for 150,000 residents. Recent studies show a salinization process in the northwest side of the aquifer. Further groundwater degradation could create major economic and social problems for the region. An infiltration-tracer test in a typical agricultural field in the Alto Piura region was carried out to explore water and solute transport mechanisms. The main objective was to mimic the mechanism of flood irrigation (25 cm head once a month), typically used by Peruvian farmers in banana plots. Soil and groundwater contaminations were monitored in an area of 3x3 m and a calcium chloride solution (3.07 m^3) was injected as tracer during the irrigation event. The initial and final conditions of the soil profile were studied by drilling boreholes prior to (3 inside and 1 outside the plot) and following (2, 4, 7 and 10 days) the irrigation event. In total, 289 soil samples were used to follow the gravimetric water content (GWC) and electrical conductivity (EC) profiles during the experiment. Soil samples were extracted in 20 cm resolution in the upper 2 m and 50 cm resolution for the rest of soil profile up to the water table, initially 4.5 m in depth. Likewise, thirty groundwater samples were taken and analyzed in for major ion concentration, EC, and total dissolved solids (TDS). Bulk density and soil texture were also measured along the soil profiles.The GWC profiles indicated a faster water movement through the unsaturated zone in respect to the salt. Infiltration test, using double ring infiltrometer, estimated Ks value of 0.24 m day^{-1} that confirmed the GWC values. The EC soil profiles indicated a clear salt accumulation in the first 1 m layer that did not manifest changes until the end of the 10 day measurement period. Groundwater samples indicated zones that reached a constant higher TDS, zones with constant lower TDS and zones of varied concentration either increasing or decreasing along the measurement period. This variability within the limited 3x3 m zone, suggests that preferential flow played a major role in the salt transport. The fast transport of salts in some areas suggests that fertilization and flood irrigation event will produce both soil and groundwater salinization. Hydrus 2D/3D model was used to simulate the water flow and solute transport. GWC data, TDS values and water table readings were used to calibrate soil hydraulic properties and dispersivity values. Simulations suggest a combined mechanism of salinization: the flood irrigation flushes down to the aquifer the accumulated solute from the first 1 m layer, producing new salt accumulation originated from external sources such as fertilizers. Simulations based on conventional Richards' equation showed up the necessity to incorporate preferential flow processes on a field-scale. Modeling of the flow and transport in the aquifer, considering the irrigation return flow effect, presents the challenging avenue of the ongoing research.

Dynamic of spatial soil moisture patterns across various time scales and depths in the TERENO forest test site Wüstebach

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Abstract

A remaining challenge in hydrology is to observe, explain and model temporal changes of soil water content (SWC) patterns across various spatial and temporal scales. Wireless sensor networks are monitoring systems continuously sensing soil moisture fields at various depths with catchment-wide coverage and at high temporal resolution. The objective of this study was to investigate the dynamic of spatial SWC patterns in the TERENO forest test site Wüstebach across various depths (topsoil – 5 cm, subsoil – 20, 50 cm), time scales (year, seasons, events) and for wettings and dryings using SWC data from 01.08.2009 to 01.08.2010 provided by the wireless sensor network SoilNet. The data were analyzed using (geo)statistics in terms of time series of the mean SWC, standard deviation (SD), nugget, sill and range and scatter plots of these parameters against mean SWC. We found that increase and decrease of spatial variability in SWC patterns are dependent on depth, soil moisture state, time scale, and wettings and dryings. We observed that (1) the variation of the mean SWC, SD, nugget, sill and range decreases with depth; (2) characteristic behaviour depends on mean SWC for all depths: Patterns occurring at mean SWC greater than a critical SWC (here ~40 Vol. %) showed mostly a linear decrease of variability in wettings and an increase in dryings; while for mean SWC less than a critical SWC variability increased in wetting and decreased in drying periods. (3) This behaviour was observed for all drying periods, while the behaviour in wetting periods in the topsoil is different for events and seasons according to different soil moisture states and the characteristic of the precipitation events, e.g. hysteresis effects have been observed in medium SWC conditions (transitions) in summer events 2009. (4) Patterns rarely push through from top to subsoil e.g. for extreme and long drying periods and extreme (long, intense) precipitation events in wetting periods. The high time resolution and continuity provided by SWC measurements via sensor networks was needed to reveal these observations, especially e.g. abrupt transitions occurring in summer wetting periods. Complex driving factors helping to explain the observations are still investigated.

Terrestrial and aquatic ecosystems of Shungite rocks

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Introduction

Shungite rocks of Karelia (Russia) represent a large group of diverse carbonaceous Precambrian rocks in an area more than 9000 square kilometers (Buseck et al., 1997). Shungite rocks have simple mineral composition, which may contain shungite, quarts, mica, carbonates and traces of other minerals. Shungite consisting of C with traces of N,O,H and S. All types of these rocks have very variable physico-chemical properties depending on the shungite structure, C content, the composition and characteristics of mineral and distribution of carbon and minerals in these shungite rocks (Kovalevski, 2008).

There are different ecosystems in the mining area of shungite rocks which change under the influence of varies agents. New terrestrial ecosystems are formed in the field of open-cast mining. Also aquatic (freshwater) ecosystems occur where spoil heaps of shungite rocks covered by water of The Onega Lake (Rozhkova, 2008). In development of ecosystems the important role is played by the organisms capable of manufacturing complex nutritive compound from simple inorganic sources, thus creating conditions for subsequent formation of communities. Such influence of a biotic component leads to rocks breaking. The aim of this study is to investigate of interactions occurring on the surface shungite rocks in the process of ecosystem development.

Experimental

The method of scanning electron microscopy (SEM) (VEGA 11 LSH TESCAN with analytical attachment INCA Energy OXFORD Instruments) was used for investigation of change of mineral composition of shungite rocks at interaction with biological objects. The study of morphological and microstructure features of carbon and minerals was carried out by transmission electron microscopy (TEM) (EM-125).

Samples of shungite rocks of a freshwater ecosystem were collected from area located in water of The Onega Lake and covered by algae. Terrestrial ecosystems were explored on the samples collected from outcropping of shungite rocks with lichens.

Results and Discussion

A shungite rock may be a substrate for formation of an ecosystem. The samples covered with a dense coat of lichens have been selected in places of shungite rocks outcrop. As a rule lichens are the first organisms occupying a substratum in the course of primary succession. Research of influence of lichens can help with understanding of some processes occurring with shungite rocks at the initial stages of development of ecosystems. Following species of lichens on the surface of shungite rocks were define: Umbilicaria deusta (L.) Baumg, Porpidia sp. The cross-section of shungite rocks covered with lichens is shown in Fig. 1. Transition layer between the lichens and the shungite rock is well visible (Fig.1a). Comparing with the original rock composition of this layer is characterized by lower content of iron and titanium, and by absence of calcium and magnesium. In addition the

concentrations of silicon and aluminum accordingly are increased. Floccus of the lichens penetrated into the substratum were usually very thin (the thickness is only 1 - 3 microns) and with long cells. They are often curved around stable minerals such as quartz and potash feldspar. (Fig.1b). In the transmission image of the field of floccus distribution, the facet of crystals is well visible (Fig.1c).

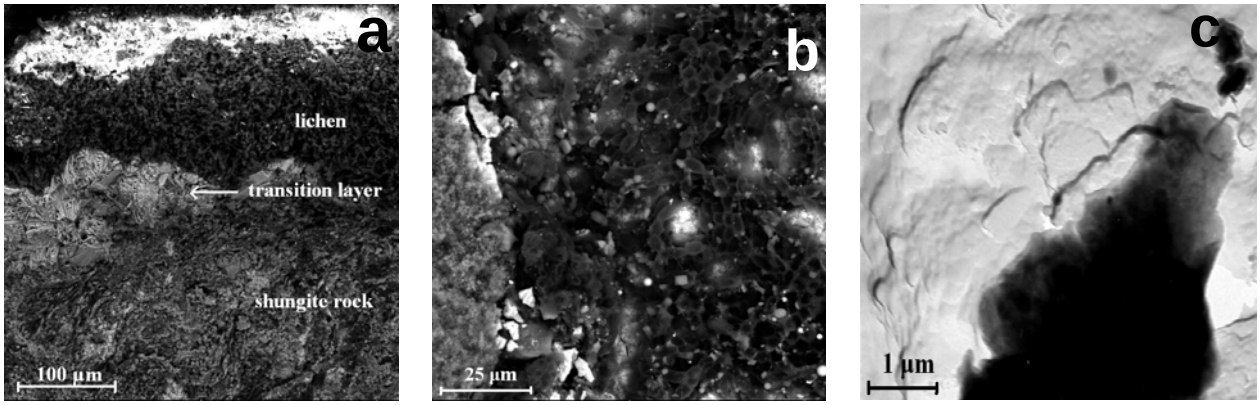

Fig.1: A lichens on a surface of shungite rocks: SEM image (a) – cross-section, (b) – a surface, (c) – TEM image (dark area in a picture – a fragment of a floccus of lichen).

An ecosystem is in dynamic state connected with adapts to factors of external environment. Shungite rocks situated in water are a substratum for development of unicellular and multicellular algae. On a surface of shungite rocks were detected considerable quantity colony count of Diatoms (Fig 2a). In some cases on a surface of shungite rocks have been found imprints of already removed diatoms (fig. 2б). The dark spots on the imprint can be interpreted as areas of the shungite rock which remained in the pores of frustule and on his raphe.

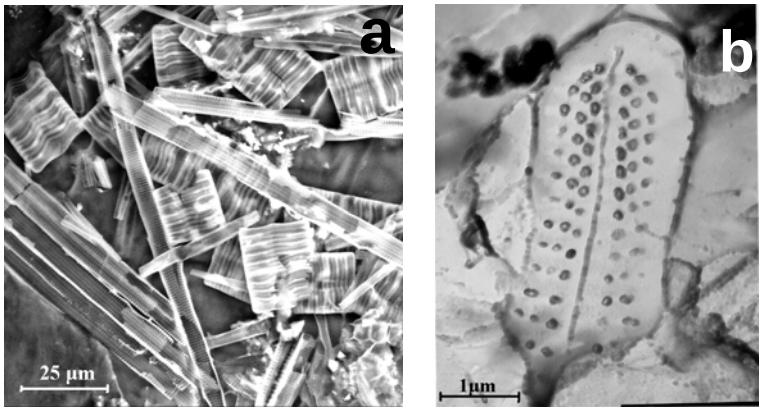

Fig.2: Diatoms on the surface of shungite rocks (a) - SEM image, (b) - TEM image.

The interaction of multicellural algae with shungite rocks lead to the separation of particles from shungite rocks by a bottom side of thallome (Fig. 3a). There are also some changes of surface morphology. Films appearing on the surface of the shungite rocks contain the to 50% oxides of iron and 40% oxide of silicon (Fig. 3b, c). All of these facts are probably attributed to vital functions of algae.

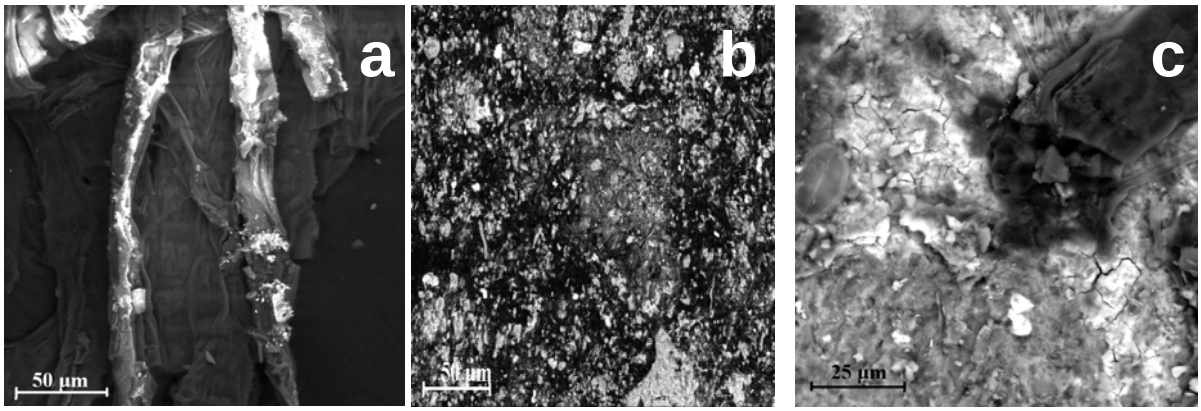

Fig.3: SEM images of a surfaces of shungite rocks: (a)- the thallus of alga, (b)- the area is uncovered by algae, (c) - the area with the fragment of algae.

Conclusions

Terrestrial and aquatic ecosystems of shungite rocks were studied. In initial development stage terrestrial ecosystem contains lichens whereas aquatic ecosystem - unicellular and multicellular algae.

Development of living organisms result in biochemical transformations, causes the change of element composition of the shungite surface. Diatoms modify the shungite surface where those are in contact, while lichens selectively spread on a surface of shungite rock and cause the less intensive processes of alteration.

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Combining neutron radiography and fluorescence imaging to simultaneously record dynamics of oxygen and water content in soils

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Summary

There is a growing need in non-destructive techniques able to measure life-controlling parameters such as oxygen, and water dynamics in every ecosystem. We propose to make use of neutron radiography coupled with fluorescence imaging to study the dynamics of these two essential biogeochemical parameters in the root-zone of plants. Measuring the real-time distribution of water and oxygen concentration enable us to understand where the active parts of the roots are located in respect to uptake and respiration.

Introduction

Survival of all ecosystems depends on the plants' functioning. Plants can survive only if water and nutrients are continuously provided to their roots. While some of the roots are in charge of plant's physical establishment, active roots take up nutrients to obtain water and consume oxygen due to respiration. Roots performance itself is variable as a function of age and local conditions such as water and oxygen availability in soil, and the same is true for micro-organisms living in the root-zone. Water content and oxygen concentrations are interrelated, because higher water content in the soil limits oxygen diffusion in soil through air filled pores. All of these root-mediated physical, chemical and biological interactions are: first, directly linked to the local dynamics of water and oxygen which are vital parameters for living organisms. Secondly, they happen in a small distance (usually less than cm) from the roots. It is technically challenging to monitor these dynamics in such a small distance from the roots without disturbing them. Non-destructive imaging methods such as fluorescence and neutron imaging have provided a unique opportunity to unravel some of these complex processes.

Material and methods

Thin boron-free glass containers were filled with fine sand of different grain sizes (inner size 10cm x 10cm x 1,5cm). The sensor foil for O2 (Borisov et al. 2006) was installed on one inner-side of the containers. We grew lupine plants in the container for two weeks under controlled conditions until the root system was developed. Then neutron radiographs and fluorescence images of the samples were taken for wet conditions, dry conditions, and a rewetting period. This procedure covers a range of water contents, and therefore a range of root activities and oxygen changes.

Results and discussion

The initial oxygen distribution is characterized by the heterogeneity of the artificial soil used. In a well aerated container the homogeneous oxygen distribution is separated by a layer of clay with lower oxygen concentrations due to smaller pore size distribution and therefore lower gas content. Figure 1 show the consumption of oxygen induced by roots of lupine plants in the range of 36 hours. By

focusing on the initial picture (figure 1, left) we made different observations. First, we observe a higher activity within the lateral roots than for the tap root. Image 2 (figure 1, centre) is taken after 11 hours of photosynthesis and transpiration. We observe that the fluorescence intensity increases in the lower and upper part of the container. Comparing fluorescence images and neutron radiography gives us the information that this effect is caused by roots. The respiration activity creates oxygen deficits close to the roots. The oxygen consumption increases with increasing root grow. Due to the high water content aeration from atmosphere is limited. Image 3 (figure 1, right) shows the oxygen distribution after 24 hours and indicates better aeration in the upper part due to decreasing water content. The lower water content is forced by plant root uptake. Regarding the lower part the oxygen deficit is still increasing due to the clay layer which prevents deeper aeration.

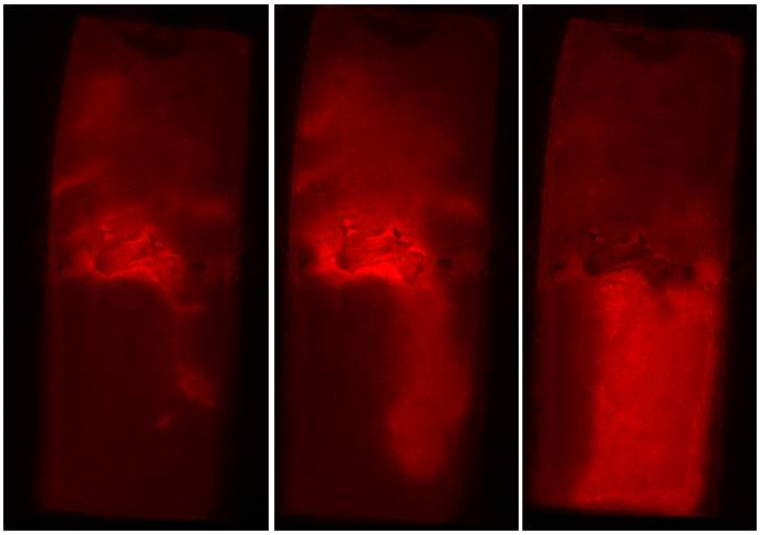

Figure 1: Development of oxygen deficits induced by plant roots over 36h (the brighter the color, the lower the oxygen content)

Conclusion

With our coupled imaging set up we were able to monitor the spatial and temporal resolution in a night and day cycle regarding the dynamics of oxygen and water content. First, this includes plant root respiration in media structured sandy soil. Secondly, we observed the transpiration driven pattern of water uptake during the same period. Our experimental set up provides the possibility to visualize both parameters non-invasively and not only as existing work for wetland plants under wet conditions.

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Primary succession of endogaeous soil fauna (Collembola, Acari) in Chicken Creek

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Abstract

Within the Chicken Creek experimental site, the successional development of the soil fauna has been monitored since site initiation in late 2005, of which the results regarding microarthropods (Collembola and the major groups of Acari) for the first five years are presented here. Collembola and actinedid mites were present within months after exposition of the substrates to the surface, albeit in very low densities and only in sporadic samples. Initially, species richness was also extremely low, with only very few species present. During the entire study period, the microarthropod communities were strongly dominated by actinedid mites. Densities and species richness increased steadily from year to year. The increases in density as well as species richness were statistically significant in all groups as of late 2007, three years after site initiation, although they were still low compared to mature soils. The increase in densities of all groups was mainly due to expanding populations of only a few species. These few “regular” species also steadily increased their distribution throughout the site. Where they were initially found only in low densities in just a few samples, they then were registered in more samples in increasing densities and finally as of 2008/2009 in all samples (Fig. 1). The increase in species richness, on the other hand, was caused by many “rare” species found in only sporadic samples and in very low individual numbers. These successional developments could be partly directly correlated with, i.e., increases in vegetation cover, indicating a direct relation to ecosystem and soil maturation.

Those species which were first present in the sites and were then most dominant in the communities are all known from initial or nutrient-poor soils and can be considered primary colonizers. Five years after site initiation these species still strongly dominated the communities. However, already one year after site initiation, specialized species adapted to xero-thermophilous habitats were also present in the sites and slowly increased their populations and distribution throughout the study period. Remarkable was the occurrence of species such as Cheletomimus vescus, Hawaiieupodes thermophilus and Xerophiles ereynetoides, which are very rare species adapted to nutrient-poor sandy soils. Increasing species richness, on the other hand, was caused by less-specialized species, which are known from mature soils, occurring in very low population sizes.

The communities were initially dominated by microbivores. As the soils developed throughout the study period, the microarthropod communities became more dominated by omnivores. Predatory species (Gamasina and Actenidida) were not present until 2007. Densities and species richness of these predatory taxa remained extremely low throughout the study and established populations of these taxa were not observable until 2009, five years after site initiation. These results indicate that soil food webs first develop from basal trophic levels and then increase in complexity during primary succession.

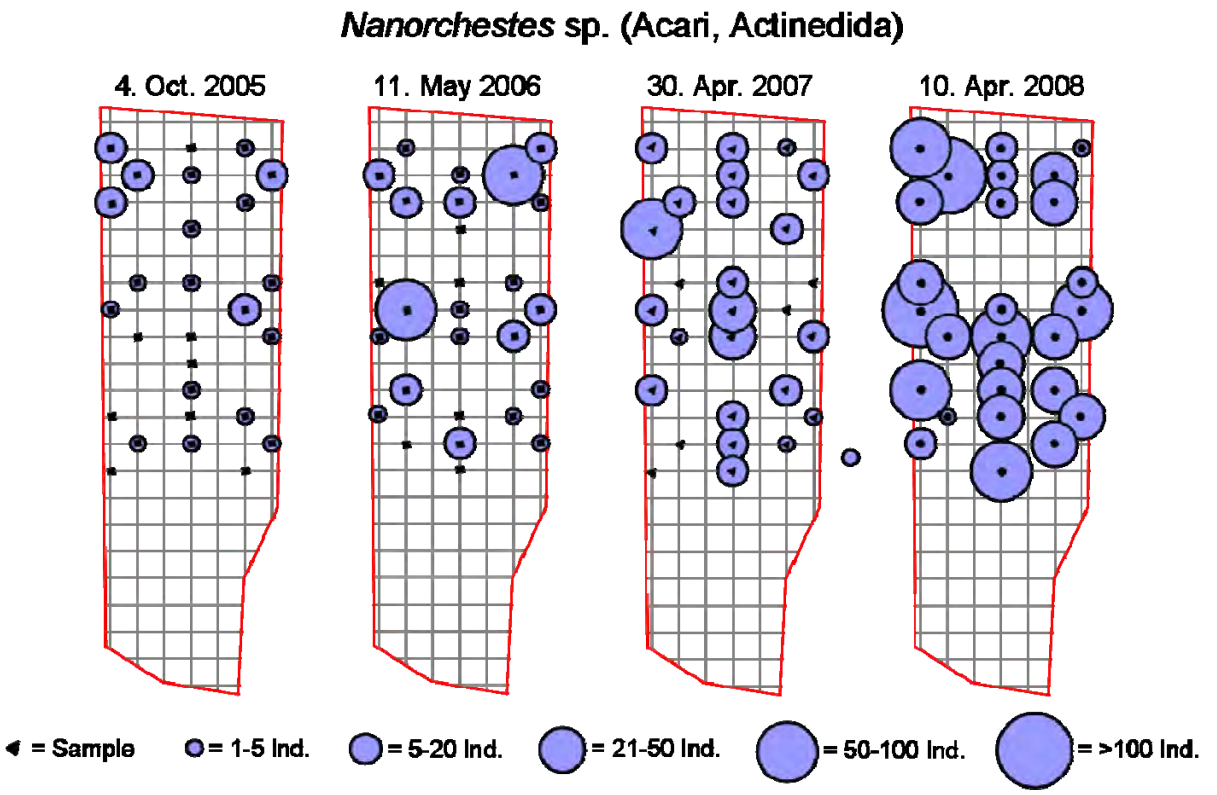

Fig. 1. Example of the increasing distribution and density of primary colonizers after and in the first years following Chicken Creek site initiation. The actinedid mite species Nanorchestes sp. 1 was the most common microarthropod in the Chicken Creek site. Locations of individual samples were slightly rotated from sampling date to sampling date to avoid undue disturbance. Densities are given in density classes (individuals per 32cm²-sample).

Formation of spatial structures and patterns during the first five years of the artificial catchment ´Chicken Creek´

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Abstract

To combine process-oriented research on initial development of ecosystems with interactions and co-development of spatial patterns and structures the Transregional Collaborative Research Centre (SFB/TRR) 38 was established as an initiative of three universities (BTU Cottbus, TU Munich and ETH Zurich).

To allow the clear definition of starting conditions at ´point zero´ and to be able to integrate spatially distributed processes and patterns to larger units, an artificial catchment was constructed in the mining area of Lusatia/Germany as the main research site (Gerwin et al. 2009). With an area of about 6 ha, this catchment ´Chicken Creek´ is to our knowledge the largest artificial catchment worldwide. It was constructed as a 2-4 m layer of post-glacial sandy to loamy sediments overlying a 1-2 m layer of Tertiary clay that forms a shallow pan and seals the whole catchment at the base. No further measures of restoration like planting, amelioration or fertilization were carried out to allow natural succession and undisturbed development. Due to the artificial construction, boundary conditions of this site are clearly defined including well documented inner structures as compared to natural catchments. It is assumed that the interaction of patterns and processes during initial development will proceed from simpler to more complex states of the systems and that different stages along this phase can be identified at the catchment level.Changes within the catchment are intensively monitored since 2005, when construction finished (Schaaf et al. 2010), including intensive on-site measurements and micro-drone based aerial images. Starting from relatively homogenous site conditions the catchment rapidly developed new structures and patterns due to soil erosion, sediment transport, stream formation, vegetation cover and succession, groundwater table rise and surface crust formation resulting in an increasing differentiation of subareas and site characteristics. Some of these structures and patterns formed as a result of the interaction of abiotic and biotic processes during initial development, some were influenced by structures caused by the construction process itself, and others were affected by single accidental events, e.g. the occurrence of high intensity thunderstorms.

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The challenge of oil sands tailings water management - the contribution of the Helmholtz Centre of Environmental Research (UFZ) to the Helmholtz – Alberta – Initiative (HAI)

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Abstract

The Helmholtz Alberta Initiative (HAI) is a collaboration between the Helmholtz Association and the University of Alberta addressing the most pressing issue of Alberta's oil sands mining: Management strategies of the large toxic tailings ponds to prevent environmental disasters, and strategies to reduce the toxicity of tailings ponds. The Helmholtz Centre of Environmental Research (UFZ) is participating with several structural units in research on processing and managing of oil sands streams and tailings waters.

Oil sands are naturally occurring mixtures of sand or clay, water, fine silts, and bitumen. When the mined oil sands are separated using warm water, the fine clays are dispersed in the water, giving large volumes of tailings that are stored in settling basins and undergo compaction and dewatering processes resulting in an extremely slow rate of sedimentation and consolidation of the fine tailings. Consequently, research on new methods for both reclaiming the existing stockpile of these mature fine tailings (MFT) and minimizing future production of wet tailings is urgently needed. In addition, potential effects of these tailings on freshwater and groundwater ecosystems must be identified and methods to evaluate and monitor such effects are required.

Taking into consideration the environmental impacts of oil sands tailing waters the UFZ projects within the HAI framework will focus on:

(1) Tailings management: Minimization of segregated tailings.

Effect of electrokinetic treatment on sedimentation and natural attenuation processes of oil sand process affected water (ELEA)

An approach to be taken by microbiologists and chemists at the UFZ will be the electrokinetically assisted sedimentation and filtration of fine solids from the oil sand process affected water (OSPW). Microbiological and chemical means of colloid destabilization will be combined with advanced methods of electrokinetically driven separation and precipitation.

(2) Background aquatic water quality and toxicological impact of released treated OSPW.

Identifying ecological effects of toxic constituents and monitoring the remediation success

The overall aim of the project is to develop an indicator system that enables the quantification of ecological effects of oil sand exploitation on non target ecosystems and a science-based environmental management regarding assessment and prediction of OSPW's effects.

(3) Advanced Treatment of OSPW for Reuse and/or Safe Discharge.

Sulphur cycling in an oil sands tailings pond

The aim of this project is a better understanding of the microbial driven sulfur cycle in a tailings pond leading to advanced water treatment strategies and optimization of the in situ degradation of a variety of contaminants.

The projects of the UFZ have the main objective to ensure the treatment, disposal and/or reuse of OSPW by improving the dewatering of tailings, the minimization of water use, and the stabilization of tailings to allow early land reclamation and potential recycling of tailings for the protection of human health and safety.

Evaluation of surface models for improving descriptions of initial changes in the 3D structure of the "Huehnerwasser" catchment

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Introduction

The development of a soil or geo-ecosystem depends on the mostly unknown initial sediment distribution as the starting point and on early redistribution processes during the initial period with sparse vegetation cover. Intensity and spatial distribution of sediment relocation can be reconstructed in models of change, based on a time series of digital elevation models (DEMs). Especially in topographically complex or non-homogeneously vegetated areas, the quantification of sediment budgets is challenging because the quality of elevation data is limited.

In this study, initial changes in the 3D sediment mass balance of the artificially-created Catchment "Huehnerwasser" are quantified. As the catchment is intensively monitored and the catchment area is consistently defined, it is well suited for the evaluation of sediment budgeting methods. The objectives of this study were

- to evaluate the viability of elevation data recorded by different methods of remote-sensing for the quantification of sediment budgets and surface structural development
- to develop and evaluate methods for the amendment of photogrammetrically derived surface models regarding their viability for the quantification of sediment budgets
- to improve the quantification of budgets by combining multi-source elevation data and integrating expert-knowledge-adapted elevation data.

Materials & Methods

TIN (Triangulated Irregular Network) DEMs depicting the catchment's surface at different stages of development have been constructed based on elevation data from digital photogrammetry, airborne laser scanning (ALS) and terrestrial laser scanning (TLS). The elevation models were subdivided into regions of differing morphodynamics (rill, interrill and alluvial areas) which have been delineated by analysis of aerial photographs.

Surface models were modified in an iterative process to successively improve their quality regarding the quantification of sediment budgets:

- Areas of falsely recorded elevation data, indicated by inconsistent development of elevations, were identified and replaced by data from other datasets.
- The drainage network's longitudinal profiles were extracted from the DEMs, elevations were modified for correct hypsography, and corrected elevations were transferred to the TIN elevation models in the rill and alluvial areas.

Elevation data in the delineated rill, interrill and alluvial areas was extracted from the datasets and recombined in additional DEMs. Three-dimensional models of volume and mass change were

constructed from pairs of two delineating 2D DEMs and sediment mass balances for different intervals of surface development were computed. The viability of surface models for the quantification of sediment mass balances was evaluated in two approaches:

- Along three cross-sections, DEM elevation information was compared to elevation data recorded by differential GPS.
- Total catchment sediment budgets were derived from 3D models of change and the balance of the sediment budget was used as an indicator of model quality.

Results & Conclusion

Elevation data from different methods of recording depict the catchment's surface in different quality, dependent on topography and vegetation structures. The 3D models of change reflect runoff-induced erosive mass relocations; however, the calculated catchment sediment budgets show different amounts of imbalance. For example, the erosion of 6358 t of sediment and the deposition of 4361 t of sediment were quantified in a 3D model constructed from two photogrammetrically-based DEMs (an amount of 2445 – 3103 t of sediment deposited in the lake has to be added to the total budget). This imbalance as well as the comparison of the DEM to d-GPS data in cross sections suggests that rill erosion is misestimated in models of change from unmodified, photogrammetrically-based DEMs. From a 3D model constructed using a combination of multi-source and modified elevation data, the erosion of 5541 t and the sedimentation of 3313 t of sediment were deduced, and cross-sections show that the modified surface model better coincides with the reference topography.

Modifying the surface models also allows an improved budgeting when multi-source data is not available: For instance, ground surface in the densely vegetated alluvial areas was only well recorded in the DEM based on ALS data, while elevations were considerably overestimated in the DEMs based on photogrammetry and TLS. Comparing 3D-models constructed from unmodified and modified DEMs to the 3D model based on ALS data, the deviation of calculated alluvial sedimentation was reduced from 36 % to 7 % and from 24 % to 5 % for photogrammetric and TLS DEMs, respectively.

By combining the advantages of different types of elevation data and modifying the DEMs based on basic logical combinations and morphological principles, an improved 3D quantification of the catchments sediment mass balance could be achieved.

Catchments as self-organized dynamic systems

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Abstract

Catchments express dynamic behaviour at a wide range of temporal and spatial scales. The infiltration rate, for example, varies at the scale of seconds and centimetres, due to feedbacks between the infiltration capacity and soil moisture and due to a heterogeneous soil matrix riddled with cracks and macro-pores. Different runoff-generating processes succeed each other, while root water uptake and evaporation compete with these processes for water. At the other end of the spectrum, geological processes, weathering, erosion and soil genesis affect the catchment structure at very long time scales.

The large range of dynamic processes in combination with an unobservable below-ground structure makes process-based modelling of catchments extremely difficult. The fact that catchments are selforganized systems makes the utility of bottom-up mechanistic models even more questionable, as the whole may not be equal to the sum of its parts, i.e. the arrangement and organization of the parts matters.

However, self-organization also gives support to the statement that "the whole is simpler than its parts" (J. W. Gibbs) and that some characteristics of the apparently complex catchment dynamics and some of the resulting steady states may be predictable after all. If we were only able to identify some generally valid principles that guide the self-organization of catchments, we might be able to cut through the clutter of individually unique catchments and focus on the relevant information that leads us to the predictable catchment functions.

This talk will summarize some of the organizing principles that have been proposed in the literature for explaining different catchment functions and give examples for their use. The talk will also discuss the advantages of this approach and some open issues.

3D development of ground surface and vegetation patterns in an initial ecosystem by means of terrestrial laser scanning

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Abstract

The initial ecosystem “Chicken Creek” is a restoration site, located in the mining landscape of Lusatia, Germany. Asides geological and hydrological parameters of this man made watershed the vegetation is a factor, which substantially determines the development of the system. To receive information about the soil surface and the vegetation cover without disturbing the development processes of the watershed a high-resolution terrestrial laser scanner was used to synchronously measure both variables.

The objective of this presentation is to demonstrate how the ground surface can be extracted and also how, in a next step, spatial models for vegetation height and vegetation density can be derived. Results will be shown on how vegetation cover is influenced by erosion and also how erosion is influenced by vegetation in turn. The limits of this method and the accuracy obtained will be another focus point of this presentation.

On the “Chicken Creek”-site the scanner was set up at thirteen points, gathering information of the whole six hectares area. To achieve a hypothetical horizontal measurement spacing of 0.1 m the scanner was mounted on a 6 m height, transportable mast. The measurements where repeated on a regular base since three years in intervals of 3-6 months. One advantage of the laser scanner approach is that soil surface and vegetation are measured simultaneously. This allows the exploration of interaction effects between erosion and vegetation. Data analysis requires separating the ground surface and the vegetation information from the laser scanner output, which is available in three-dimensional point clouds.

Water quality and aquatic ecosystems in the irrigation run-off lakes of arid Central Asia

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Abstract

The increasing area of arid croplands for irrigated agriculture, combined with poorly-managed use of industrial fertilizer and heavy application of pesticides, have altered the natural landscapes of many arid regions. Such intensive anthropogenic activities can shift hydrologic regimes and lead to the formation of new ecosystems in the resulting landscapes. The Khorezm region of Uzbekistan illustrates such an area and is representative of the bulk of the irrigated regions of Central Asia, which is one of the largest irrigated areas worldwide (Fig 1).

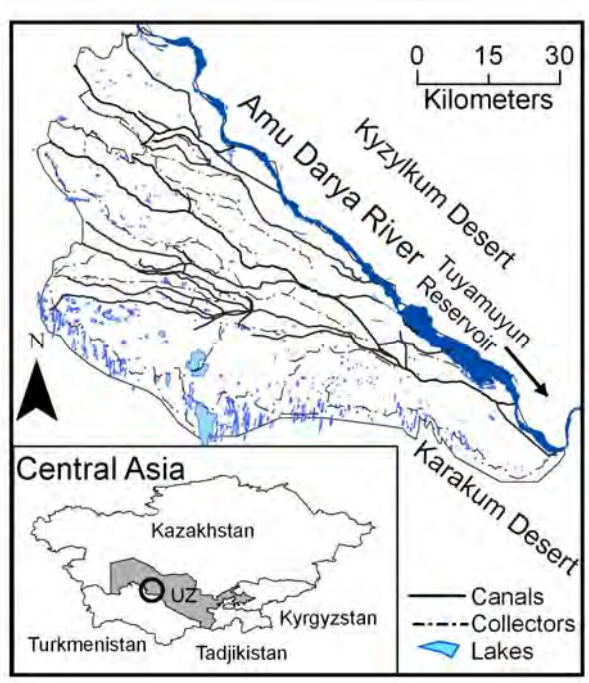

Figure 1. Map of Khorezm, Uzbekistan, showing the Amu Darya River, large irrigation canals drawing water from it, and the many small lakes in the region.

Khorezm was once a broad expanse of Central Asian floodplain forest (locally known as Tugai) flanking the Amu Darya River as it flows between the Karakum and Kyzylkum deserts on its way to the Aral Sea. However, under Soviet rule in the 1960's, a vast network of irrigation and drainage canals was built throughout the entire Central Asian region, including Khorezm, to provide cotton for the Russian textile factories. By the mid-nineties, over 9,000 km of irrigation canals were constructed to supply irrigation water to about 270 ha of cropland in Khorezm, but only about 11% of these canals were concrete-lined (Vodproject 1999), resulting in high amounts of seepage from the canals and

rising ground water tables, and in turn leading to (secondary) soil salinization across the region. Therefore, as Uzbekistan rapidly became a leading exporter of raw cotton, irrigation run-off water filled natural depressions in the landscape, forming a series of shallow lakes. Remote sensing analysis detected 421 lakes with an area of at least 1 hectare (ha) in Khorezm (Kaiser 2005). Preliminary age dating of lake cores suggests that lake sediments are on the order of one-hundred years old. Little is known about the ecology and water quality of these lakes.

During the study period 2006-2008, we examined the water quality and aquatic foodwebs of four representative lakes in the Khorezm region. The lakes were found to be very shallow, with a depth of ~1-3 m but widely-varying water levels throughout the year. Input water stems primary from irrigation drainage canals and likely only a small amount of groundwater (Scott 2009). The soils of Khorezm are considered to be of low fertility (Martius et al 2004), leading to the application of heavy fertilizer loads. Although officially 160-250 kg N ha^{-1} is applied on average to the major crops cotton and winter wheat each season, actual application rates are likely higher (Djanibekov 2008). Therefore, as endpoints for the irrigation runoff, high levels of nitrogen (N) and phosporus (P) species were expected in the lakes as well. However, N and P levels in the study lakes were generally low. For instance, maximum and average ammonium concentrations over all lakes were 3.00 mg N/L and 0.62 mg N/L, respectively, with ammonium as the dominant N species. Total P was always below 0.5 mg P/L. Patterns of nutrient concentrations were similar across the lakes. Ammonium peaks occurred in the winter/spring (Fig. 2), which did not correspond to the timing of fertilizer application to surrounding fields during the growing season (March-September). Therefore, the lakes may receive nutrients from a source beyond the surrounding fields, such as the large Tujamujun reservoir on the Amu Darya River just upstream of Khorezm (Fig. 1).

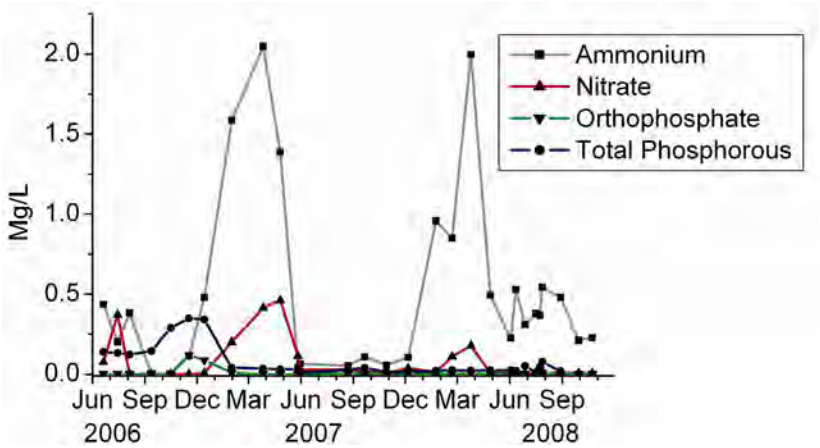

Figure 2. Nitrogen and phosphorous concentrations in Shurkul, one of the study lakes in Khorezm, Uzbekistan. Similar patterns of nutrient concentrations were observed among the four study lakes.

Dissolved oxygen concentrations were normally well-mixed throughout the water columns of the lakes, and inversely correlated with seasonal water temperatures, which ranged between 2 and 30°C during the study period (Fig. 3). Salinity in the lakes was generally moderate at 2 – 12 g/L, but increased in several lakes in 2008 in response to low water levels during drought periods. Despite reported heavy application of polarized pesticides such as DDT in the past, only very low levels of such pollutants were measured in the lake water column (Nishonov et al. 2009).Mysid shrimp were commonly found along the littoral areas of the lakes, along with dragonfly and damselfly larvae as the most abundant macroinvertebrates. Primarily introduced species of fish were found in the lakes, including goldfish,

silver carp, grass carp, snakehead, catfish, bream, and pikeperch. Fishermen were observed to harvest fish for local consumption at all lakes. Although further analyses will include stable isotopes to determine foodweb linkages within the lakes, the water quality conditions found presently in the lakes suggest they may be suitable for irrigation, aquaculture, or recreational uses.

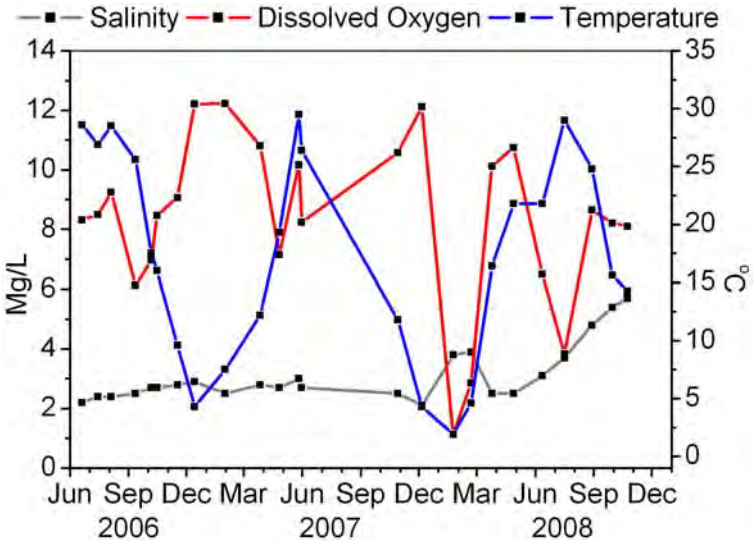

Figure 3. Physical water quality conditions in Shurkul, one of the study lakes in Khorezm, Uzbekistan.

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Biodegradation of petroleum hydrocarbons in oil sands tailings settling basins in northern Alberta, Canada

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Abstract

Bitumenextraction from oil sands oresyields large volumes of tailings that are deposited in settling basins/pondsfor consolidation.Currently,tailings ponds in northern Alberta, Canadacontain about 850 million m^3 of oil sands tailings.Our laboratory studies have shown thatlow molecular weight hydrocarbons (C_3-C_{14}) present in the organic solvents entrained in tailings arebiodegraded by the indigenous microorganism in the tailings ponds to produce methane. Onlyshort-chain n-alkanes (C_6-C_{10}) and certain BTEX compounds were readily metabolized but long acclimation periodswereneeded for microbes to degrade branched alkanes in organic solvents. Molecular analyses revealed diverse microbial communitiesinvolved in hydrocarbon degradation in oil sands tailings. Understanding biodegradation of hydrocarbons as well as predicting methane emission from oil sands tailings pondsis important for effectivemanagment tailings andgreenhouse gas emissions.

How do biological soil crusts influence hydrological processes in initial ecosystems?

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Abstract

During initial ecosystem development vegetation cover is sparse, but the space between shrubs is not bare and is often covered by biological soil crusts (BSC) composed by cyanobacteria, green algae, mosses and lichens. These cryptogames are the first colonizer of initial ecosystems. BSC accumulate the first soil organic matter and influence the hydrological processes (Fischer et al. 2010a, 2010b).

In southern Brandenburg (NE Germany) it was possible to study the development of BSCs during intital ecosystem genesis on the artificial water catchment “Hühnerwasser” in the recultivation area of the lignite open-cast mining district. At this catchment substrate-dependent water availability defines the crust types. The mosaic-like pattern of the BSCs was associated with the distribution of fine-grained material. We defined three types BSC: (a) initial cyanobacterial and green algae crusts on the soil surface (BSC-I). (b) cyanobacterial and green algae crusts on the soil surface between sparse vegetation cover e. g. with Trifolium arvense (BSC-II). (c) BSCs with few mosses (BSC-III) between dense vegetation.

To compare the different crust types, chlorophyll amount as well as organic matter content were determined, and the structure of the crust was investigated using optical and scanning electron microscopy. In addition, we characterized the water regime of the crusts using water infiltration and repellency tests to determine the repellency indices by using the ethanol/water microinfiltrometer method (Hallett and Young, 1999).

Water infiltration was influenced by two factors: (i) the crust type, where infiltration rates were highest on almost bare substrate (BSC-I) and least when cyanobacteria and green algae formed a dense cover on the surface, and (ii) the texture. Compared to BSC-II, infiltration rates were elevated in BSC-III, pointing to decline of surface sealing when mosses penetrated the dense microphytic crust.

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Initial forest ecosystem on hard coal mining waste dumps in the Upper Silesia

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Abstract

In Poland, output of 1 Mg of hard coal was accompanied by 0.4 - 0.5 Mg of carboniferous waste. In the 1980's, production on the level of 200 million Mg of coal accompanied about 100 million Mg of waste. In the early of 1970's, conception of central dumps development from 50 up to 1000 ha area arose. The most of them were intended for afforestation. Research conducted on the oldest, over 40 years old central dump "Smolnica" (50 ha area) dealt with substrata as abiotic element of ecosystem (chemical, mineralogical content, petrography and granulometry of waste and prognosis tests for sulphide weathering) and biotic elements (biological weathering, fauna and flora composition, enzymatic activity, colonization by fungi). Studies concerned also problems of functioning of forest ecosystem in dependence on level of trophism of substrata, with emphasis on forms and role of nitrogen and sulphur in forest ecosystem development. Results showed, that sulphide weathering was a dominant factor, affecting initial forest ecosystem.

Carboniferous wastes from „Szczygłowice" mine are dumped on „Smolnica" heap and belong to Upper Carbon (Pensylvanian) following the stratigraphic units, that means from orzeskie, rudzkie and siodłowe formations (300-500m) [Strzyszcz 2003]. In petrography content claystones prevails mudstones and sandstones. Taking into account the mineral compositon of wastes, quartz, feldspar, micas, chlorites dominate over carbonates, sulphur and organic compounds. In respect of chemical content SiO2, Al2O3 and Fe, K, Na compounds are obtained. Characteristic of chemical content is prevailing Mg content over Ca. Wastes are abundant in K but poor in P. Organic carbon content varies from 1,76 to 13,06 % and total N content - from 0,19 to 0,42%, but mineral forms of nitrogen (mainly NH4) vary from 0,2 to 2,3% N total. Assuming that among abiotic factors, in first stage of ecosystem forming, main role play physical and chemical weathering, fraction <25mm can consist of claystone (5-88%), mudstone (0-7%) and sandstone (0-11%). Physical weathering is accompanied by chemical-biological processes of sulphides weathering (mainly pyrite) carried out by mesophilic microbial consortia containing mainly Acidithiobacillus ferrooxidans, At. thiooxidans. Dynamic of this process is illustrated by pH_{H2O2} of wastes in first six month. On area of $1m^2$ pH_{H2O2} of 10 cm layer varies from 3,6 to 6,4; on area of $10m^2$ - from 5,0 to 6,1; on area of 100m2 - from 5,1 to 7,0; on area of $1000m^2$ - from 3,2 to 5,6, and on area of 1 ha varies from 3,0 to 8,2. There has been worked out a method of inhibition of this process by applying ground phosphate rock (Fig.1a). Projection of pH of dumped material for biological reclamation purposes is based on reaction measurements both in H_2O and H_2O_2. This test shows buffering abilities of dumped material. pH reaction of wastes from „Smolnica" dump averages (pH in H_2O and H_2O_2 respectively) for sandstone: 7,5 and 3,8; mudstone: 7,5 and 4,1; claystone: 7,2 and 4,2; carboniferous shales: 6,0 and 2,6 and for syderite 7,3 and 3,8. Lysimeter studies in six year period show lack of salinity hazard for forest initial ecosystem. According biological weathering, intensity of decomposition of wastes depends on bacterial strains. The highest ability for decomposition was observed in bacterial culture with Artchobacter and Pseudomonas. Main source of carbon for microorganisms is coal [Włodarczyk, Strzyszcz 2007]. Microbiological activity is accompanied by enzymatic activity. Introduction grasses on heap after 7 years, caused increase of

activity of dehydrogenase, catalase, invertase, beta-glucosidase, content of the last two was highest under Festuca rubra and Festuca heterophylla. Under trees increased activity of dehydrogenase, catalase and invertase was observed, and the highest ability to stimulation enzymatic activity had alder (Alnus glutinosa) [Osmańczyk-Krasa 1987]. On 4-6 year old experimental plots in two vegetation period, 45 species of macromycetes had been stated. Most of them were forest fungi-saprophytes from Basidiomycetes and 4 species from Ascomycetes. Species such as: Thelephora terrestris, Paxillus involutus, Laccaria proxima, Lactarius rufus, occurred commonly (Fig.1b). Highest amount of fungi species were stated under poplar clones (Marilandica, Hybrida '275'), less under great maple, red oak, ash and larch. Moreover, under deciduous trees (poplar, oak), the appearance of fungi species (Thelephora terrestris, Lactarius helvus), typical for coniferous trees was observed [Lisiewska, Siedlaczek 1982]. In the first stage of entering of spontaneous vegetation on dump significant role plays availability of soil nutrients. In the period of 5 year, on plots fertilized NPK, value of product of medium species number and medium percent of plots covering by vegetation was twice higher than on plots fertilized only N [Strzyszcz et al. 1981]. This tendency remains unchanged for next 30 years. Presently forest understorey consist of 30 species, 17 of them is related to typical forest phytocoenosis. Higher share of forest species was observed on fertilized plots [Stolarska et al. 2006]. Secondary forest community, developed on course of succession, typify variability of stand density (0,4-0,9), age and species composition. Main tree species applied in reclamation on "Smolnica dump were: scots pine, red oak, larch, ash, poplars. Under forest stand of reclamation origin, soil organic sub-horizons Oie or Oea from 1 to 4 cm thick developed. Comparative forest research (d.b.h, h, Kraft classes) in 40 years old scots pine stands on various plots (fertilized, non-fertilized, natural ground) did not reveal significant differences [Stolarska et al. 2006].

Figure 1. Applying ground phosphate rock on area of intensive pyrite weathering (a), Paxillus involutus under 5 years old larch (b).

Reassuming, development of initial ecosystems on carboniferous wastes is determined by following factors: time, trophic level (occurrence of available forms N and P) and first of all sulphide weathering. Studies conducted on 90 years old carboniferous waste dump in Essen that is totally covered by black locust stand [Burghardt et al. 2009], show that up to 100 cm depth, ground has acid reaction (pH_{H2O}3,8-4,3 and pH_{CaCl2} 3,1-3,7) that makes correct development of forest ecosystem difficult. Dumping carboniferous wastes together with power plant ashes appears purposeful and it has been employed successfully in Upper Silesia.

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Bacteriology of miliolite, a bioclastic limestone: Diversity and their possible potential activity in weathering of miliolite

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Introduction

One of the principal mechanisms that influence elemental recycling on the Earth's surface is "weathering." For a long time these processes have been considered mainly from the strictly physical and chemical point of view. However, as microorganisms are ubiquitous on every solid surface on Earth, many weathering processes can be driven by the presence of microbial activity (Gorbushina and Krumbein, 2005). Throughout the world a wide attention has been paid by many scholars in weathering of carbonate rocks which is an important link in global carbon cycling, alkalinity generation, cycling of major and trace elements (Cubillas et al., 2005; Garcia., 2006). However the knowledge on microbial activity in weathering mechanisms is not yet fully established and the diversity of bacteria inhabiting the carbonated rocks is still an enigma. Miliolite is a bioclastic sedimentary rock of the most abundant rock types in karsts areas of Saurashtra and Kachchh where these deposits spread over nearly 5,300 km. Miliolite is predominantly made up of calcium carbonate. Geomorphological, chronological and geochemical studies of these deposited are well established (Bhatt. 2003). Miliolites undergo weathering and forms red soil sequences which are important landscapes in the Saurashtra and Kachchh. Bacterial activity and their mechanisms in weathering of miliolite deposits are of interest towards conceptual understanding of microbial mediated weathering.

Materials and methods

Miliolite limestone samples were collected from an exposed weathering profile located at Gopanath, Saurashtra, Gujarat, India. The chemical composition of the limestone was determined by X-ray fluorescence (XRF). Carbonate dissolving bacteria were isolated and enumerated on miliolite agar and Deveze-Bruni medium (Cacchio et al., 2004). Carbonate dissolving bacteria were characterized for their ability to bring about drop in pH of growth medium, organic acid production, mineral phosphate solubilisation and Siderophores production. Organic acids were estimated by High performance liquid chromatography (HPLC). Molecular microbial diversity of miliolite dissolving bacteria was performed based on amplified 16S rDNA restriction analysis (ARDRA). In situ microcosms were set with potential carbonate dissolving bacteria to elucidate their role in weathering of miliolite. Bacteria-treated miliolite samples were analyzed by scanning electron microscopy (SEM) and X-ray diffraction (XRD)

Results and Discussion

The predominant chemical component of the miliolite sample was found to be CaO (47%) by XRF. Fourteen bacterial isolates were found to be strongly influencing dissolution of miliolite (Fig. 1). Phylogenetic studies based on ARDRA analysis (Fig. 2A and B) revealed four different groups of bacteria that were abundantly distributed in miliolite limestone. These bacteria were identified as Staphylococcus sp., Bacillus sp. and Actinomycetes sp by 16S rDNA sequencing analysis. The principle mechanism involving in miliolite weathering by these isolates was mainly due to calcite dissolution by excreting extracellular organic acids. These acids were found to be acetate, lactate,

pyruvate and malate by HPLC. Among all the bacterial isolates, Staphylococcus sp. M16 had a best ability in dissolving calcite. In situ microcosm experiments with three different bacterial genera revealed the bacterial activity in dissolution of calcite and subsequent miliolite weathering. It was found that Staphylococcus sp M16 released significant amount of Ca^{2+} from miliolite (1200 ppm) by production of 161.3 mM lactate, 47.28 mM acetate and 0.88 mM oxalate. Other isolates (Bacillus sp. and Actinomycetes sp) were also found to be significant in calcite dissolution and Ca^{2+} release from miliolite. Calcite dissolution was confirmed by XRD pattern. High amount of Ca^{2+} was released when lactate and acetate appeared to be major organic acids (Huang et al., 2006). Apparent decrease in surface area of rock, pitting, boring and erosion of miliolite were well documented by SEM. Results obtained from bacterial physiology indicated that , these bacterial species were able to get nutrients form miliolite as a result miliolite dissolution occurs. The bacterial colonization on miliolite surface was clearly observed by SEM. Present study extends our conceptual understanding of microbial mediated carbonate weathering and initial processes of soil formation in karst ecosystems.

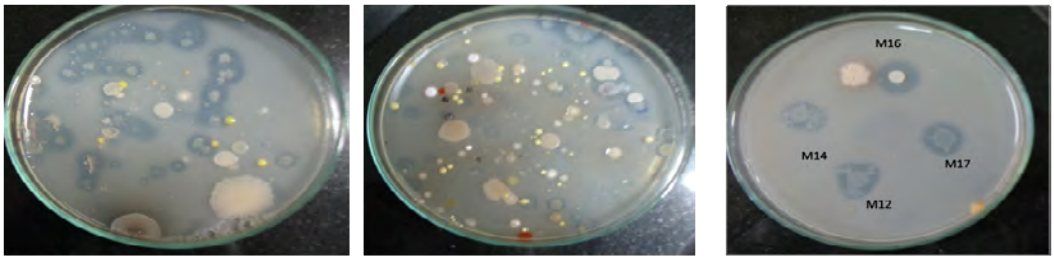

Fig. 1: Carbonate dissolving bacteria on Miliolite agar (A&B). Clear halo zone on agar plate indicates the carbonate solubilisation. Pure cultures of bacterial isolates are also shown (C).

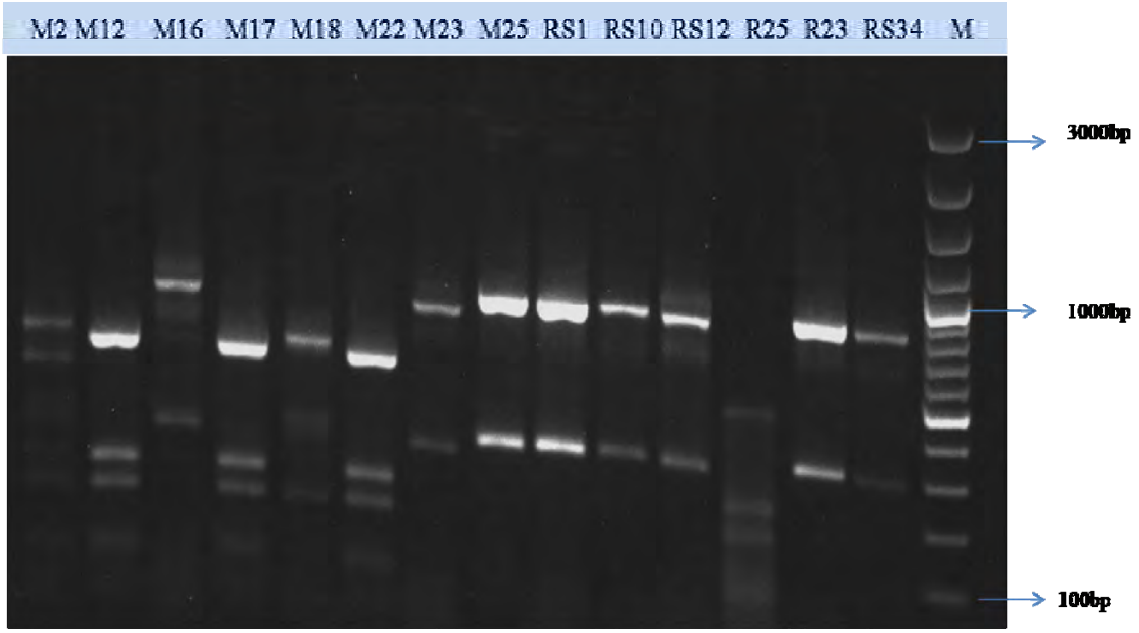

Fig. 2 A: ARDRA pattern of carbonate dissolving bacteria.

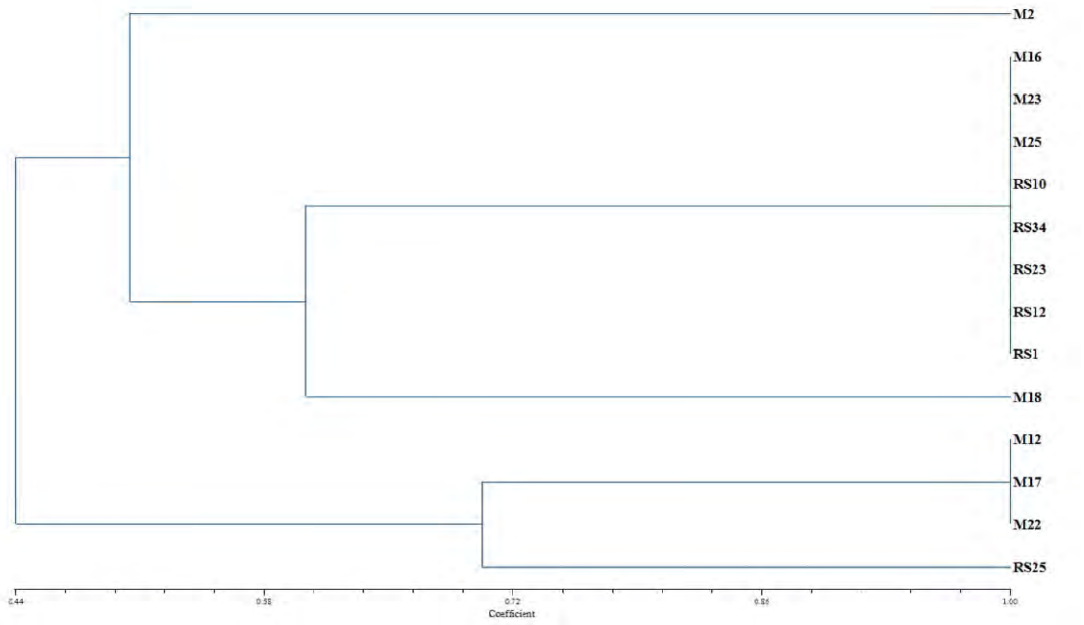

Fig. 2B: Phylogenetic relationship among carbonate dissolving bacteria based on ARDRA.

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Simple landscape evolution models as tools in the exploration and understanding of processes at catchment scale

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Introduction

Our understanding of combined geomorphic, pedological and ecological systems at large spatial scales is insufficient - although in many cases, individual processes at small scale are well understood (Reinhardt et al., 2010, Murray, 2009). This limited understanding at larger scales is frustrating because it is mainly at the landscape and larger scales that our influence as humans is felt and where our policies have impact.

When studying systems that are insufficiently understood, initial modelling efforts are of a descriptive nature, with more complex and more predictive models being developed in later stages, as system understanding increases. This has happened to a certain degree in landscape evolution modelling, where the first three-dimensional models were simple and descriptive (Kirkby, 1971), but complex, modern models can be used for prediction – at least for reaches and catchments of well-studied rivers (the CAESAR model - Coulthard et al., 2000). During this gradual switch to more complex models, the character of studies typically changes from deductive to inductive. In inductive studies, observations are primarily done to increase system understanding (and hence, to improve model equations). In deductive studies, system understanding has increased (mode equations are somewhat fixed) and observations are increasingly geared at model calibration.

Along this scale, our understanding of the coupled human, biological, and physical (or human-bio-physical) landscape at the landscape scale is more in an inductive than in a deductive phase. Much of our current understanding is qualitative or at much smaller scales. The recent start of important observation sites (like Chicken Creek, but also the Critical Zone Observatories in the US) is expected to provide the first comprehensive sets of quantitative observations at the landscape scale. Based on these observations, hypotheses can be made and tested – with the use of initially simple models.

We therefore argue that the need for such simple modelling techniques is far from over, and that much can still be gained from their continued use in the study of human-bio-physical landscapes. Here, we will illustrate a few of those gains, using our simple landscape evolution model LAPSUS (Schoorl et al., 2002) as a platform.

Testing of hypotheses about plant-soil interactions

In a study in Israel, LAPSUS was used to model the interaction between shrub growth and soil processes. Shrub growth was assumed to alter soil properties, and soil erosion and deposition was assumed to alter the environment that shrubs grew in. Equations for plant growth and soil erosion and deposition were taken from existing studies (Buis et al., in press) – but interactions were hypothesized.

The model experiment initially used hypothetical straight slopes of 6° to isolate the interactions of interest from those caused by landscape heterogeneity. For three scenarios of rainfall (100, 200 and 300mm mean annual rainfall), altitude change after 100 years of interaction was recorded for parallel-slope transects (Fig. 1). With limited rainfall (A), shrub mound formation dominated the response. With strong rainfall (C), gully and rill formation dominated.

Model results were then iteratively compared with field observations along similar transects and conclusions were drawn about the validity of the assumed interactions.

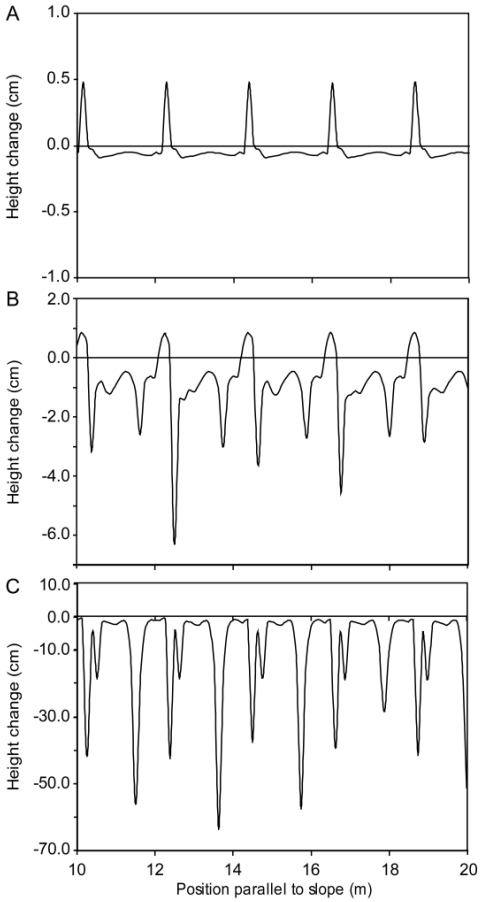

Fig. 1: Altitude change along a parallel-slope transect after 100 years, for three different scenarios of rainfall. A: 100 mm annual rainfall, B: 200 mm annual rainfall, and C: 300 mm mean annual rainfall.

Exploration of the future

In a study in KwaZulu-Natal in South Afrca, LAPSUS was calibrated to model the landscape evolution of the area for the last 50.000 years, using five different landscape processes and explicit vegetation interaction (Temme and Veldkamp, 2009). Using the calibrated parameter set, LAPSUS was then run forward in time up to the year 3000 for both a stable climate scenario and a changed climate scenario (Temme et al., 2009). The changed climate scenario was bsaed on the work of (Tadross et al., 2005).

Fig. 2 shows the result of that analysis, allowing a first appraisal of the possible effects of climate change on landscape change over the millenium timescale in our study area. Redistribution of material, due to the five landscape forming processes, is expected to be more extreme under changed climate than under stable climate – including potentially beneficial effects from increased re-deposition of fertile eroded material.

The fact that LAPSUS is a simple cellular automaton model allowed us to calibrate it with data of the last 50.000 years. The model's validity over that timescale gave us some confidence in its exploration of climate effects for the future.

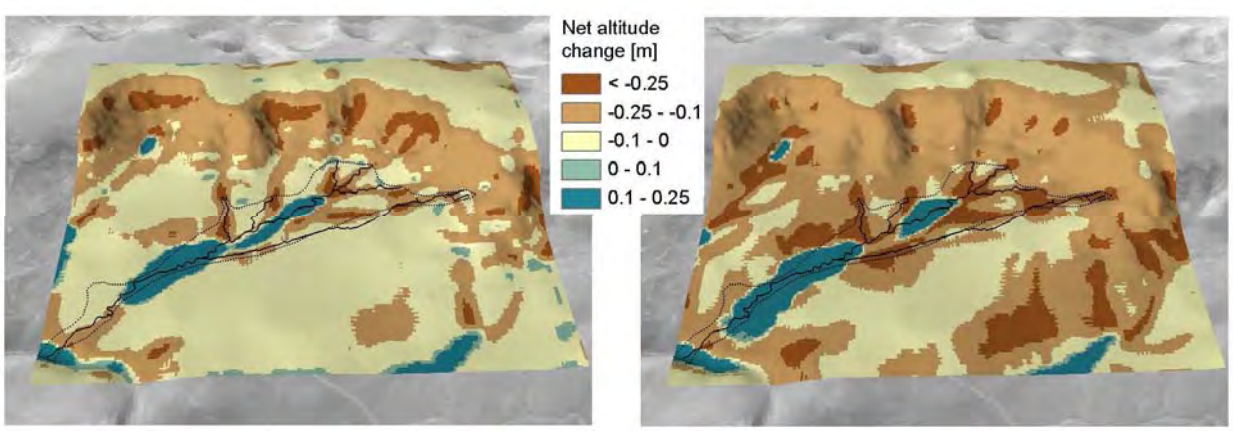

Fig. 2: Study area in South-Africa with predicted net change in altitude due to landscape and vegetation processes between the year 2000 and the year 3000 under stable (left) and changed (right) climate.

Use in sensitivity analysis

In the same valley in South Africa, the sensitivity of conclusions to different model parameter values was assessed. For seven zones in the study area, we used Monte Carlo-type sensitivity analysis to test the hypothesis that average altitude change in each zone was not different between stable and changed climate. The probability that the hypothesis was correct was calculated after every 100 years between the year 2000 and the year 3000 (Fig. 3). Probabilities are extremely low for most zones, indicating that climate change is very likely to affect landscape and vegetation interactions.

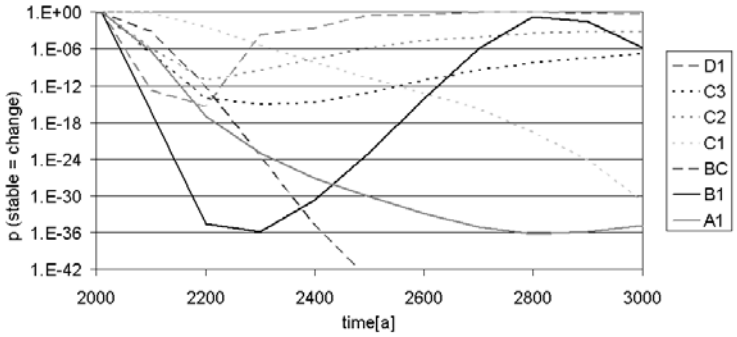

Fig. 3: The probability that landscape development under stable and changed climate is the same, for the period from the year 2000 to the year 3000, and for seven zones in the study area. For the analysis underlying this figure, LAPSUS was run 200 times for 1000 years.

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Aquatic-terrestrial linkages along succession gradients at the catchment scale

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Abstract

Rivers are linked ecosystems where terrestrial and aquatic habitats overlap, creating a zone where they interact, the aquatic-terrestrial interface. The interface or boundary between aquatic and terrestrial habitats is an area of transition, contact or separation; and connectivity between these habitats may be defined as the ease with which organisms, matter or energy traverse these boundaries. Coupling of aquatic and terrestrial systems generates intertwining food webs, and we may predict that coupled systems are more productive than separated ones. For example, riparian consumers (aquatic and terrestrial) have alternative prey items external to their respective habitats. Such subsidized assemblages occupy a significant higher trophic position than assemblages in unsubsidized areas. Further, cross-habitat linkages are often pulsed; and even small pulses of a driver (e.g. short-term increases in flow) can cause major resource pulses (i.e. emerging aquatic insects) that control the recipient community. Short-term additions of resources, simulating pulsed inputs of aquatic food to terrestrial systems, suggest that due to resource partitioning and temporal separation among riparian arthropod taxa the resource flux from the river to the riparian zone increases with increasing riparian consumer diversity.

In this presentation I will focus on the effect of geomorphic style, succession stage, and productivity gradient on functional linkages between the aquatic and the terrestrial realms. In dynamic systems, for example, vegetated islands function as critical instream riparian areas that contribute substantially to total ecotone length, and create diverse aquatic and terrestrial habitats Linking habitats that differ in their capacity to produce, store, and transform organic matter and nutrients may increase the overall functional performance of an entire ecosystem. Finally, the relative extent and the spatiotemporal dynamics of dry and wet areas within a catchment may control greatly the capacity of the river network to efficiently retain nutrients and organic matter. All these findings provide new opportunities for the future management of riparian corridors.

Abundance of microbes involved in nitrogen transformation in the rhizosphere of Leucanthemopsis alpina (L.) HEYWOOD grown in soils from different sites of the Damma glacier forefield

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Abstract

Glacier forefields are an ideal playground to investigate the role of development stages of soils on the formation of plant-microbe interactions, as within the last decades many alpine glaciers retreated, whereby releasing and exposing parent material for soil development. Especially the status of macronutrients like nitrogen differs between soils of different development stages in these environments and may influence plant growth significantly. Thus in this study, we reconstructed major parts of the nitrogen cycle in the rhizosphere soil/root system of Leucanthemopsis alpina (L.) HEYWOOD as well as the corresponding bulk soil by quantifying functional genes of nitrogen fixation (nifH), nitrogen mineralization (chiA, aprA), nitrification (amoA AOB, amoA AOA) and denitrification (nirS, nirK, and nosZ) in a 10-year (10a) and a 120-year (120a) ice-free soil of the Damma glacier forefield. The results were linked to the ammonium and nitrate concentrations of the soils as well as to the nitrogen and carbon status of the plants. The experiment was performed in a greenhouse simulating the climatic conditions of the glacier forefield. Samples were taken after 7 and 13 weeks of plant growth.

Generally, the data revealed much higher differences between bulk soil and rhizosphere in the 10a soil, displayed by higher gene abundances.

Interestingly, only in the 10a soil the plant nitrogen concentration increased over time and simultaneously the plant C/N ratio decreased. Two possible sources of nitrogen can be considered: Firstly, more ammonium was allocated by nitrogen-fixing microbes in the 10a soil, as indeed the nifH gene abundance was highest in the rhizosphere in this soil after 7 weeks. Secondly, recent studies showed (Lipson et al. 1998, Schimel et al. 2004) that plants under nitrogen limitation do not only rely on microbially derived ammonium or nitrate but are also able to assimilate low weight organic nitrogen like amino acids. Although amoA AOB and chiA gene abundances did not increase significantly over time ammonium concentrations significantly decreased. It might be speculated that ammonium concentrations decreased due to higher nitrification rates, elevated plant uptake or a combination of both. The assumption of higher nitrification rates is underlined by the study of Schimel et al. (2004), who stated that nitrification activity is repressed in pioneer ecosystems, whereas it is favoured in

developed ones, where nitrifying and mineralizing microorganisms live in closer association to each other. Thus, mineralizing and nitrifying microbes could have developed a stronger interaction, which is further underlined by the similar abundance pattern of both genes.

While, nirK gene abundance did not differ in the two soils with highest gene abundances in the rhizosphere, nirS only occurred in the bulk soil of the 120 a soil, indicating a niche separation of the two nitrite reductases. In contrast to the constant appearance of nirK, nosZ gene abundance was very dynamic with significantly increasing gene abundance after 13 weeks of plant growth. As the N_2O/N_2 ratio of denitrification products is positively related to nitrate concentrations (Dendooven et al. 1994), the declining nitrate concentrations in all samples might have boosted the growth of the nosZ-harbouring microbial community. Additionally, the nitrous oxide reductase is most sensitive to low amounts of oxygen (Morley et al. 2008, Otte et al. 1996). Thus, it was not surprising that highest nosZ gene abundances were detected in the rhizosphere of L. alpina after 13 weeks of development, where a more pronounced root system was developed presumably entailing a lower oxygen partial pressure (Rheinbaben et al. 1984).

In conclusion, the data revealed a stronger rhizosphere effect in the 10a soil in comparison to the 120a soil, reflected by much higher gene abundances in the rhizosphere compared to the bulk soil. Interestingly, only plants cultivated in the 10a soil were able to accumulate remarkable amounts of nitrogen.

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Successional change in plant community structure and carbon dynamics during mire development

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Introduction

Mires are wetland ecosystems that accumulate peat due to imbalance between net primary production and decomposition. Along peat accumulation environmental conditions for plants and microbes change; consequently there are changes in mire functions such as carbon dynamics. Succession in mires has traditionally been studied using palaeoecological methods. Although this historical approach is powerful to reveal replacement of plant species during mire development it cannot be used to study change in ecosystem functioning.

Along the Finnish coast of Bothnia Bay land uplift is still taking place at the rate of ~7mm yr-1. In this region primary mire paludification occurs in the depressions between the coastal dynes. Consequently, a primary successional series of mire ecosystems, from young fens in the first step of primary paludification to ombrotrophic bogs in older stages, can be found when moving inland from the coast line.

In this study, we used the spatial continua of pristine mires to study the link between successional pattern of plant communities and the change in carbon dynamics of mire ecosystem.

Methods

The study includes seven study sites representing mires of different age, peat depth, height above sea level and nutrient status. Together the sampling covers the first three thousand years of mire development (Merilä et al. 2006). Current plant community composition (cover, leaf area) were studied concurrently with chamber measurements of CO_2 and CH_4. Carbon accumulation and historical plant communities were studied from peat cores.

Results and Discussion

In the first stages of succession, here called as wet meadow stage, vegetation was dominated largely by pioneer species of forbs and sedges that are able to rapidly spread vegetatively. Moss layer was patchy and dominated by brown mosses. In fen communities Sphagnum mosses formed dense and extensive hummocks supporting shrubs (Vaccinium oxycoccos and Andromeda polifolia), while the wetter surfaces were covered by sedge species and herbs. The ground layer of bog communities was formed by extensive Sphagnum fuscum mats and dwarf shrubs, while Sphagnum balticum and sedges dominated in wetter depressions.

Plant communitity structure and hydrology appeard to be the key factors in regulating carbon dynamics: photosynthesis, respiration and CH_4 emissions. Hydrological stability resulting from peat accumulation increased during the succession. At the first stages water level depended on the precipitation and varied greatly during growing season. Lowered water level during a dry growing season resulted in the decreased leaf area of the vascular plants. This in turn was reflected in the decreased level of photosynthesis and methane emissions.

While the succession proceeded and the peat layer grew in thickness, its water holding capacity increased. Consequently the water level in bog communities remained rather constant despite the changes in precipitation. Therefore, leaf area, the rate of photosynthesis, respiration and methane emissions depended less on the weather conditions and were more stable in bog than in fen stages (see also Leppälä et al. 2008, 2010).

Currently results from the study are used on evaluation of new of Holocene peatland model (Frolking et al. 2010).

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Non-native plant invasion – a threat for ecosystem development in Bangladesh

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Abstract

Exotic species have become a major focus in ecology, conservation biology and biogeography as many ecosystems' development are threatened by the invasion of alien species. (Simberloff, 2005; Underwood et al., 2004). This problem of biological invasions by exotic species is considered as one of the most important components of human-induced global environmental change. Bangladesh is one of the highly populated countries in the world (1099.3 people km^{-2}). The geographical setting of Bangladesh makes the country more vulnerable to natural disturbances like flood, drought, cyclone and storm surge, erosion, landslide etc. Initial ecosystem development in forest ecosystems of Bangladesh are under tremendous threat due to a number of anthropogenic and natural disturbances. Various anthropogenic activities like deforestation, encroachment, increased consumption of forest resources etc. combined with natural disturbances promote the establishment of exotic species which are already causing threats to ecosystem development through impeding natural regeneration and growth of different native species in the forest ecosystems. The objective of the study was to develop a landscape-scale predictive model of the occurrences of non-native species in Satchari reserve forest in Bangladesh. Our strategy was to find out at which landcape exotic species richness was more and therby threatening ecosystem development and simultaneously to identify the key factors for that richness. We performed detrended correspondence analysis (Hill and Gauch, 1980) using R-package "vegan" version 1.15^{-1} (Oksanen et al. 2008) to interpret exotic species' distribution at landscape scale and to visualize the explanatory power of those key factors for this distribution at the same scale. DCA has the advantages of detrending and rescaling over other correspondence analyses. Ordination analysis (DCA) separated the three different sites on an "exotic species" gradient (richness/occurrence) along the first axis though the sample plots did not cluster tightly together (Figure 1).The DCA indicated that the optima as well as the distribution of exotic species was closely related to the surrounding areas of Satchari reserve forest which consist mainly of fallow lands and tea gardens and receiving high amount of disturbances. The predicted distribution of exotic species was largely driven by these disturbances. This means that an increased distribution of exotic species was observed within the surrounding areas of Satchari reserve forest which has been subjected to threat for initial ecosystem development. Biological invasions alter the nature of ecosystem development through altering the fluxes of energy, water and nutrients (Vitousek et al, 1987).

Our approach provides valuable information for land managers to better manage non-native species for better ecosystem development.

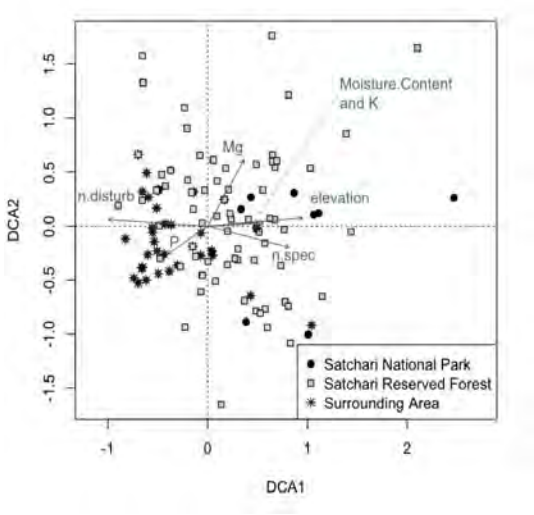

Figure 1: Biplot of DCA output with sample plots (points) and different variables (vectors) for the exotic species recorded in the study area. The abbreviations n.disturb and n.spec stands for number of disturbances and number of species respectively.

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Characterization of bacterial communities during primary succession on spoil deposit sites after brown coal mining in Czech Republic

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Heading

This study describes the development of bacterial communities in soils of a newly developing ecosystem on mine deposit sites in central Europe, where large areas of soils are used for spoil deposition after brown coal mining. Artificial ecosystems are established where initial substrate is almost free of microbial life. Such sites represent a unique opportunity to study soil development during primary succession or revegetation. The aim of this work was to characterize the succession of bacterial communities along a chronosequence of spoil deposits after brown coal mining in the Sokolov area, Czech Republic.

We selected sites developing spontaneously for 6, 12, 21 and 45 years. The 6-year-old site had no vegetation cover, the 12-year-old site was covered by grasses and herbs; shrubs of Salix and Populus dominated the 21-year-old site and the 45-year-old site was covered by Betula and Populus trees. A 21-year-old reclaimed with Alnus was used for comparison to primary succession.

Microbial biomass was quantified using PLFA analysis and qPCR and bacterial communities were characterised using a phylogenetic microarray combined with sequencing. The content of Corg and N increased while pH decreased in the course of succession. Bacterial biomass was always higher than fungal and bacteria dominated the 6-year-old site. Fungal/bacterial biomass ratio increased from 0.11 over 0.25 and 0.32 to 0.20 along the succession. Microarray data showed a clear separation of the youngest 6-year-old site from the other sites, which were much more similar for each other. Subsequent cloning confirmed microarray data. The 6-year-old site was dominated by e. g. Spiroplasma, Paracossus, Desulfosarcina, Propionibacterium . The site revegetated with Alnus was similar to the spontaneous succession site of the same age showing high effect of soil C accumulation and low effect of vegetation.

Our results show that a specific bacterial community develops in initial stages of succession under low C conditions and in the virtual absence of fungi. Among its members, most do not occur in the later stages of succession.

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Acute responses of the soil ammonia oxidizers to zinc.

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Abstract

Ammonia oxidation, the rate-limiting step of nitrification, has been intensively studied due to its importance in biogeochemistry and sensitivity to various environmental factor shifts and stresses. Ammonia oxidation in soils was considered to be performed to the greatest extend by bacteria residing in the β-proteobacterial class (bacterial ammonia oxidizers - AOB) (Kowalchuk and Stephen 2001). Recent metagenomic approaches in combination with a study of a marine crenarchaeal isolate indicate the involvement of an archaeal guild (archaeal ammonia oxidizers - AOA) (Konneke et al. 2005; Treusch et al. 2005). Following this discovery, studies investigated the long-term responses and adaptation of both AOB an AOA to trace-element stresses. Still, trace-element acute effects on the occurrence, composition, and expression of related molecular markers of both AOB and AOA have been greatly overlooked and thus the vast amount of underlying information has been neglected.

The present study is an attempt to thoroughly analyze events occurring in these microbial guilds caused by high Zn concentrations in soil. In a soil microcosm approach Zn concentrations ranging from 0 to 5000 mg/kg were applied. Treated soils were leached and sampled for biological measurements in triplicates after overnight incubation. pH and Zn concentration shifts were monitored post Zn addition and after leaching. The potential nitrification activity was determined and amoA gene (encoding A subunit of AMO - ammonia monooxygenase, responsible for ammonia oxidation) presence and transcriptional response, as well as AOB 16S rDNA transcripts were analyzed. AOB amoA transcripts experienced a more immediate negative response to Zn concentrations (Figure 1) and in a genotype specific manner (Figure 2) compared to the respective AOA. Bacterial ammonia oxidizer 16S rRNA abundance shifted in accordance to the bacterial amoA abundance indicating a total loss of activity along the Zn gradient (Figure 1). amoA gene enumeration showed that the highest applied Zn concentration lead to an intensive loss of bacterial amoA copies, indicating an AOB viability loss. Highlights of the generated dataset will be discussed.

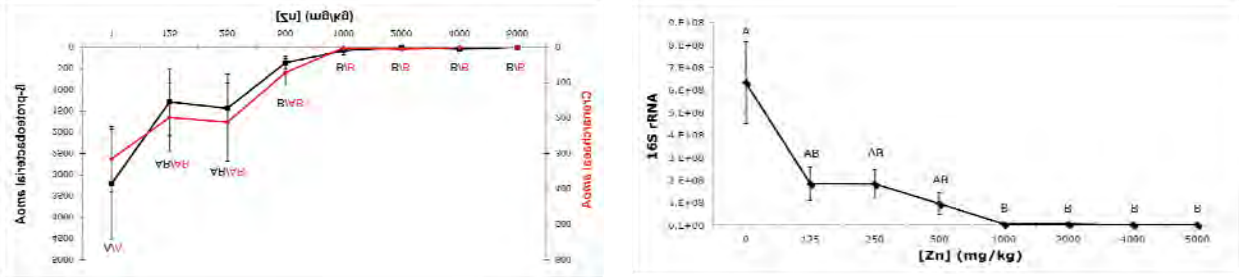

Figure 1 qRT-PCR results of β-proteobacterial and crenarchaeal amoA transcripts (left) and β-proteobacterial 16S rRNA (right) after incubation in various Zn concentrations. Letters indicate significant differences between treatments according to ANOVA and Tukey(HSD).

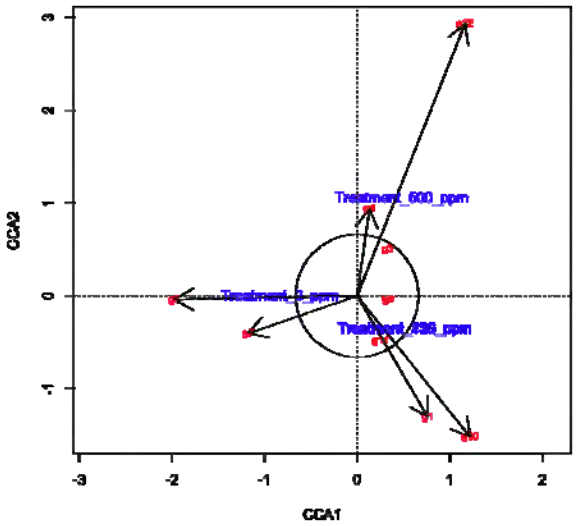

Figure 2 Canonical Correspondence Analysis biplot of observed genotypes with centroids of the treatment triplicates for β-proteobacterial amoA transcripts. Genotypes residing outside the equilibrium circle are considered responsible for the observed variance and mostly related to the treatments whose vectors form a smaller angle with arrows aiming to the respective genotypes. Microcosm centroids are presented according to the nominal Zn concentrations in ppm (mg/kg).

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Plant succession trajectories in the initial development of an artificial catchment

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Abtract

Background and hypotheses: Two main vegetation succession theories (Egler 1954) describe the vegetation development on bare parental material: 1) The relay floristic concept indicates that the initial species composition positively support the occurrence of species of the later succession phases. And 2) the initial floristic composition concept assume that even species of the later development phases may occur in the initial phase and have the potential to impact the whole succession in their floristic composition. For a large landscape unit of six ha we tested, if and how the vegetation development results in vegetation patches and patterns in an artificial, slightly sloped water catchment in Germany (Gerwin et al. 2009). We contribute to three questions: 1) Does the pattern development of the vegetation follow the slope gradient with an decreasing ground water level? 2) Do the vegetation succession of the artificial catchment follow one of the main theories on vegetation succession? 3) Do small differences in e.g. the soil nutrient supply, ground water level or the soil texture produce the vegetation patches and patterns?

Methods

118 vegetation records in one m² plots were distributed in a grid of 20m x 20m from 2006-2009 (Zaplata et al., accepted). The species composition was analysed in multivariate ordinations and with univariate statistics. Maps of the vegetation patterns were developed with ArcGIS using the spatial analyst tool.

Results

The vegetation succession differentiates at the quite homogenously constructed catchment. The patterns develop do not clearly follow neither one of the succession theory nor the slope gradient. The pattern development will be presented and discussed.

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Weathering of granite rock in the Damma glacier forefield

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Abstract

At the glacier forefield, the availability of nutrients is usually very low. Mobilization of nutrients from rock material through weathering processes plays a crucial role to overcome this limitation (Bernasconi 2008). Microorganisms and plants modify their local environment by various exudates including organic ligands, siderophores and also cyanide, which is a very important agent during the initial period of colonization and soil formation. We study the weathering mechanisms of primary rock-forming minerals in terms of intrinsic (e.g. mineralogy, surface area) and extrinsic weathering factors (e.g. pH, Eh, concentrations of ligands). Rocks and weathered stream sediments were obtained from the Damma glacier area (Central Alps, Switzerland) at approximately 2,200 m a.s.l.

Influence of hydrological factors was interpreted from the grain-size distribution and the mineralogical composition of the sediment samples. The Damma Reuss guarantees continuous water availability than the remote areas. Four different water regimes were classified and shown in table 1.

Tab. 1 Water regimes of the Damma glacier forefield

Aspects	**O**pen area	**P**rotected by rocks
Close to the Damma Reuss	CO	CP
Far from the Damma Reuss	FO	FP

CO: At location that is close to the shore of Damma Reuss and open, we observed the exportation of the easily weatherable minerals (e.g. apatite and plagioclase-albite) within the silt and clay fraction.

CP: Location that is close to the shore of Damma Reuss and protected by large rocks (CP) shows alluvial placer deposition because lower flow velocity and accessibility of water. These spots exhibit the evidence of distinct sedimentation.

FO: The open-remote area exhibits lower influence of alluvial placer deposition contributes to lower sedimentation than the rock-protected remote area.

FP: Location that is remote of the Damma Reuss and protected by rocks, the different mineral compositions of the sand fraction from remote area in comparison to the sediment from riverbank suggest other parent rocks. Moreover, slow meltwater from the side moraines cause an increase in the fine fractions.

The analysis by X-ray diffraction and Rietveld show pronounced similarities in mineralogical composition among the sediments. The materials are composed of quartz, muscovite, microcline, albite, epidote, biotite, chlorite and apatite. The effect of physical weathering was observed from the depletion of feldspars in grain-size fraction <250 µm. In clay fractions, epidote and apatite are exposed, whereas both minerals, in the larger fraction are grown in feldspar preventing their weathering. The samples from the forefield show a very low content of apatite and biotite, which are the main candidates of nutrient-releasing minerals.

In addition to field observations, weathering of crushed granite was investigated in controlled lab experiments. At 25°C, the influence of cyanide was studied in batch reactors as function of pH and cyanide concentrations. The concentration of cyanide was maintained by a constant partial pressure of hydrogen cyanide through gas bubbling. Thus, the concentration of cyanide anion strictly depends on pH. Proton- and cyanide-promoted dissolutions were investigated at pH 6 by leaching of the mineral fraction in 30 hours. Sample solutions were filtered through nylon membrane and elemental analyzed with inductively coupled plasma-optical emission spectrometry. Preliminary results show that the presence of cyanide in the solution caused a suppression of iron in comparison to cyanide-free conditions (Fe in Fig. 1). Due to the interaction between iron and phosphate, one can expect an increase in phosphate concentration as a consequence of iron suppression.

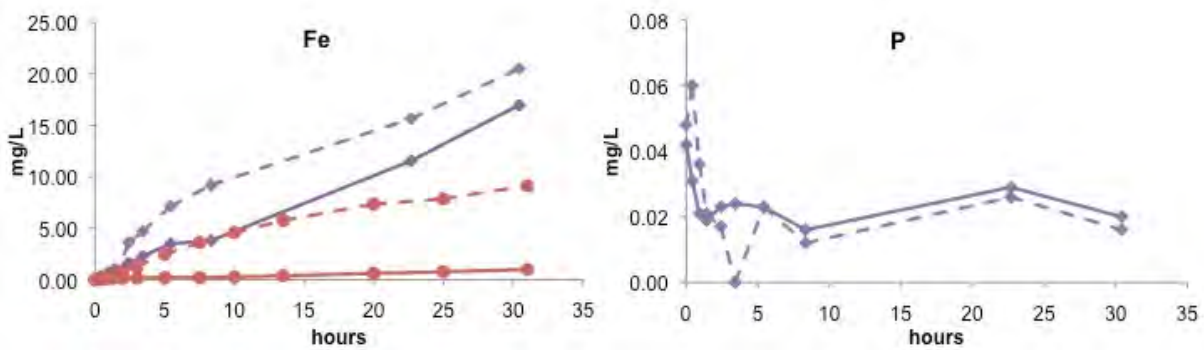

Fig. 1 The effects of cyanide on dissolution of granite from the Damma glacier under oxic conditions at pH 6 and 25 °C. The elemental concentration of iron (Fe) and phosphorus (P) are shown in parallel batch experiments. Dashed lines indicate elemental concentrations in absence of cyanide and the solid lines indicate concentrations in presence of cyanide.

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Soil nitrogen availabilities are linearly correlated with tree growth in jack pine forests in the oil sands region of Alberta

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Abstract

Linking soil nitrogen (N) availability with tree growth is important for understanding how forest productivity is affected by soil N supply. However, quantitative relationships between soil available N indicators and tree growth are lacking in the oil sands region of Alberta. In this study, in situ and laboratory aerobic and anaerobic N mineralization rates were determined for both forest floor and 0-20 cm mineral soils for eight jack pine stands in the oil sands region in northern Alberta. Tree growth of the last six years and potential N availability (measured using Plant Root Simulators – PRSTM probes) were also quantified. The results showed that soil N availability varied among those forest stands and N availability was several times higher in the forest floor than in the mineral soil over the growing season. Most of the N availability indices studied was linearly correlated with tree growth rates (ring width) of the jack pine trees. The potential N availability in the mineral soil was positively correlated with tree ring width as well. We conclude that quantitative relationships between soil N availability indicators and stand growth could be established for jack pine forests, where the in situ and laboratory aerobic and anaerobic N mineralization rates can be used as surrogates for predicting tree growth. Such relationships can potentially be used as an analog for guiding reclamation practices in the disturbed landscape where jack pine type of ecosites dominate in the oil sands region.

The early successional phase of an artificial initial ecosystem - solved and open questions

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Abstract

In the artificial Chicken Creek catchment (6 ha, Brandenburg, Germany), constructed in 2005, we studied the colonising plant species, their possible entry pathways via soil substrate (soil seed bank) and wind (seed rain) as well as the vegetation development. The surveys enabled us to understand the population dynamics of the dominant early colonisers, and for Conyza canadensis even to prove a temporal shift from large-scale sink to source dynamics.

Peak abundances of some colonising plant species occurred early in time. E.g. Chenopodium album was present with most individuals already in 2006, the first vegetation period after catchment construction, and Conyza canadensis in 2007 (fig. 1). In the respective following growing season the population densities of the two annual pioneer species decreased significantly. While the population increases are well comprehensible according to our data and the existing theoretical concepts, such early decreases are hard to explain.

Our data indicate that life-processes of the dominating species C. canadensis do not match with its performance over time: We actually observed both absolute and relative decrease of the Conyza population. However, the life-processes that drive succession (individual seed production, far reaching seed dispersal by wind, establishment, and intraspecific competition derived from population density) gave reason to expect a further increase in importance.

Thus we suppose other processes to play an important role, namely decreasing nutrient availability after catchment construction at first. We will introduce these ideas (by formulating the “initial nutrient peak hypothesis”) and will discuss possibilities to test them.

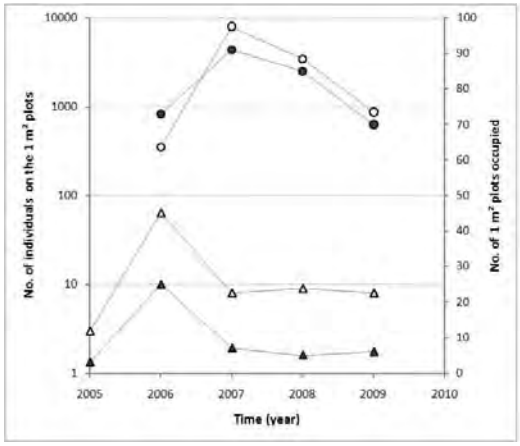

Fig. 1: The quickly passed early successional phase in ‘Chicken Creek’ catchment. It mainly was formed by Conyza canadensis (O) and Chenopodium album (Δ). The figure shows their total individual numbers and plots occupied (filled symbols). Note the logarithmical scale of the primary y-axis.

Ecological development of soil microbial communities in rehabilitated quarries

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Abstract

Quarries are an important type of degraded land in southern China requiring ecological improvement and rehabilitation. In this study the ecological development of a soil microbial community was examined in terms of microbial composition at different rehabilitated phases in three quarries, namely Turret Hill Quarry (TH), Lam Tei Quarry (LT) and Shek O Quarry (SO), in Hong Kong. One phase (rehabilitated in 1994) was studied in TH, three phases (rehabilitated in 1998, 2001 and 2004) in LT and four phases (rehabilitated in 1998, 2001, 2004 and 2006) in SO.

Results showed that LT01 had the highest number of fatty acid methylesters (FAMEs), and SO98 followed at 0-5 cm depth (Tab. 1). The newly rehabilitated sites (LT04, SO04 and SO06) had the lowest number of FAMEs. There was a similar trend for the number of FAMEs at 5-10 cm depth. Similar patterns were shown by FAME peak areas which indicated microbial abundance. LT01 and SO98 had the highest peak areas at the two depths, while LT04, SO04 and SO06 were lowest. Using individual FAMEs as biomarkers, the relative abundances of G+ bacteria, G- bacteria, fungi, actinomycetes and AM fungi were higher in 0-5 cm depth than in 5-10 cm depth. The group of G- bacteria dominated in all sites, in which cy19:0 represented more than 15% of the total extracted FAMEs in all soils tested, except those of SO06 at 5-10 cm depth. The groups of bacteria (including 14:0 and 17:0) found at TH and LT, however, were absent in SO. AM fungi decreased in abundance with the increasing ages in SO and LT. Principal component analysis, using the total FAME profiles of two soil depths, revealed a scattered distribution for all sites and clearly separated soils from the old sites and the new sites.

Tab.1 Total number and peak area of FAMEs detected in soils at different phases of the three quarries

Sites	Number	Area		Number	Area
	0-5 cm			5-10 cm	
TH94	26b	79176b		18ab	41369ab
LT98	24bc	65616b		16ab	32568bc
LT01	36a	196309a		21a	61893a
LT04	18cd	47223b		15ab	25041bc
SO98	32a	90594ab		21a	58955ab
SO01	20bcd	41152b		15ab	28397bc
SO04	15d	30129b		13b	25585bc
SO06	17d	33307b		12b	9533c

Our study suggests that oxygen and C availability in soils played a dominant role driving the changes in the structure and composition of G- bacteria (Fierer et al., 2003). C substrate availability also played an important role in the development of G+ bacteria community (DeGrood et al., 2005). Higher abundance of fungi and AM fungi was found in younger phases, which implied that available phosphorus was the limiting factor for regulating fungal and AM fungal communities in our local quarries (Acosta-Martinez et al., 2007). Artificial planting of leguminous species and adding phosphate fertilizer should be strongly recommended during the early period of rehabilitation.

Mean values followed by the same letter are not significantly different at p=0.05 level according to the Tukey's HSD test.

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Characterization of interactions between soil solid and liquid phase in the initial ecosystem development

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Abstract

In the initial phase of soil formation interactions between solid and liquid phases and processes like mineral weathering, formation of reactive surfaces and accumulation of organic matter play a decisive role in developing soil properties.

As part of the Transregional Collaborative Research Centre (SFB/TRR 38) 'Patterns and processes of initial ecosystem development' in an artificial catchment, these interactions are studied at the catchment 'Chicken Creek' (Gerwin et al. 2009). To link the interactions between soil solid phase and soil solution at the micro-scale with observed processes at the catchment scale, microcosm experiments under controlled laboratory conditions were carried out.

Main objectives were to determine the transformation processes of C and N from litter decomposition within the gaseous, liquid and solid phase, the interaction with mineral surfaces and its role for the establishment of biogeochemical cycles.

The microcosm experiments were established in a climate chamber at constant 10 °C. In total 48 soil columns (diameter: 14.4 cm; height: 30 cm) were filled with two different quaternary substrates (sand and loamy sand) representing the textural variation within the catchment at a bulk density of 1.4-1.5 $g*cm^{-3}$. The columns were automatically irrigated four times a day with 6.6 ml each (corresponding to 600 $mm*yr^{-1}$). The gaseous phase in the headspace of the microcosms was analysed continuously for CO_2 and N_2O contents. C and N transformation processes were studied using ^{13}C and ^{15}N labelled litter of two different plant species occurring at the catchment (Lotus corniculatus, Calamagrostis epigejos) that was incorporated into the microcosm surface. All treatments including a control ran with four replicates over a period of 40 weeks. Two additional microcosms act as pure litter controls where substrate was replaced by glass pearls. Litter and substrate were analysed before and after the experiment. Percolate was continuously collected and analyzed in two weeks intervals for C and N contents (including ^{13}C), pH and ion concentrations.

The initial phase is characterized by intense leaching from both litter materials and substrates. Base cation concentrations show different characteristics for the two substrates: whereas calcium is leached in high amounts, magnesium and especially potassium leached from the litter are strongly retained in the soil indicating cation exchange. The addition of litter material results in a respiration flush due to easily available organic substances at the beginning of the experiment. L. corniculatus litter with low C/N ratio is decomposed much faster compared to C. epigejos. DOC and TDN leaching are strong influenced by substrate texture. TDN leaching and nitrification processes are constrained in treatments with L. corniculatus. DOC leaching is much higher from loamy than from sandy substrate.

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Microbial Community Succession along the Damma Glacier Forefield

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Abstract

As the majority of Swiss glaciers are currently receding through global warming, the glacier forefields have become an interesting study site for primary microbial succession and the main drivers of this colonization. Glacier forefields worldwide have been studied, revealing that the community composition of bacteria includes both autotrophs and heterotrophs in all soil ages (Nemergut et al., 2007, Schmidt et al., 2008). The community structure changes from bacteria dominated to fungi dominated in a time from 20 year-old soils to 80 year-old soil in phospholipid fatty acid analysis (PLFA) (Ohtonen et al., 1999). Archaea and fungi are generally undersurveyed in this type of habitat. Nicol reported that mainly crenarchaeota are colonizing a glacier forefield in the Austrian Alps (Nicol et al., 2005, Nicol et al., 2006). Jumpponen investigated the fungal population on the Lyman Glacier in the Cascade Mountains, identifying all main groups of fungi on the forefield, mainly ascomycetes and basidiomycetes (Jumpponen, 2007). It was also shown that soil depth, vegetation cover, water content, organic carbon as well as soil texture are the main factors influencing the succession and the biomass formation along a forefield (Kastovska et al., 2005, Yergeau et al., 2007, Schutte et al., 2009). Also soil age, the rock type, pH and other environmental factors and influence the microbial communities (Noll & Wellinger, 2008, Lazzaro et al., 2009).

Here, we characterized the structure and composition of bacterial, archaeal and fungal communities in newly exposed rock substrates on the Damma glacier forefield in central Switzerland. Soil samples were taken from 22 different sampling sites along the forefield ranging from the fine granitic sand near the glacier terminus devoid of vegetation, until well developed soils covered with vegetation. Thus the soil age ranges from 0 to 136 years (Fig.1). The microbial communities were studied with genetic profiling (T-RFLP) at the 22 sampling sites and sequencing of clone libraries at the three selected sites 1, 7 and 18 (2 year-old, 62 year-old and 110 year-old soil). This is the first study to investigate these three microbial groups at the same sites on a forefield, along with the environmental parameters pH, base saturation, carbon and nitrogen content and plant cover.

Bacteria were the most diverse as shown by the highest Shannon diversity index of the TRFLP profiles (ranging from 2.3 – 3.4), whereas archaea (SDI: 0.1 – 2.0) and fungi (SDI: 0.3 – 1.2) were considerably less diverse along the forefield. The major bacterial lineages found are proteobacteria, actinobacteria, acidobacteria and cyanobacteria. Only acidobacteria rise in numbers of clone sequences in the libraries along the forefield, whereas the other groups tended to decrease. The most striking finding was that euryarchaeota were predominantly colonizing young soils and crenarchaeota mainly mature soils. Fungi shift from an ascomycetes dominated community in young soils to the more plant symbiotic basidiomycetes community in old soils. Redundancy analysis (RDA) indicated that the community composition changed along the forefield for all three groups, the fungal community showing the highest variance. The RDA analysis also indicated that the environmental parameters measured indeed are important drivers for the microbial succession along the forefield. Base

saturation and pH are mostly affecting the young soil communities and C and N content as well as plant coverage affecting the old soil communities. Thus the soil communities are changing along with the changing soil parameters.

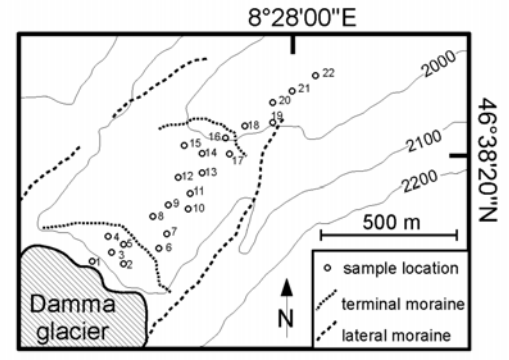

Figure 1: View of sampling sites 1 to 22 along the Damma glacier forefield, showing also the two lateral moraines from 1850 and the 1927 and 1992 terminal moraines. Sites 1 to 5 represent the young, unvegetated soils (2 to 13 years), sites 6 to 17 the intermediate soils (57 to 77 years) and sites 18 to 22 the old soils (110 to 136 years). The glacier terminus today can be seen on the lower left corner, the two end moraines are the differentiation lines between the soil ages.

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