Degradation of soils on upland sites can influence biogeochemistry of soils of wetlands in catchments by sedimentation of nutrients and minerals. The aim of this project is to detect soil degradation of upland soils by stable isotopes of carbon, nitrogen and sulfur. Preliminary results of this study are presented here.

Because of the different metabolisms in oxic upland soils and anoxic lowland soils the influence of eroded material to lowlands should be detectable by stable isotopes of carbon, nitrogen and sulfur. The isotopic signature of sulfur differs distinctly between wetlands and upland systems (Alewell & Novak, 2000). Here, we test if this difference can also be found for nitrogen and carbon isotopes.

The sampling site is located on "Seebodenalp" on 1020 masl. in Central Switzerland. Samples were taken from erosion sources in the upland and from erosion sinks in directly influenced wetlands. Additionally, the wetland was sampled in an area that is not affected by erosion. A shift of nitrogen isotopic signature of the wetland was found in comparison to the signature of the upland which was interpreted as the result of soil erosion on the upland site. Carbon isotope signatures did not show any difference between upland and wetland soils.

REFERENCE

Black carbon (BC) is globally present as an inert residue resulting from vegetation and fossil fuel burning. BC has a diverse nature, and there are various methods with which to measure it (thermal, chemical, optical, indirect). An international ring trial was initiated to compare these different methods of analysis. Twelve reference materials were chosen as standard reference materials for BC measurement. To validate if the reference materials were chosen appropriately to be representative of natural materials, we chemically characterised the twelve reference materials using elemental analysis, \(^{13}\)C CP and BD NMR and \(\delta^{13}\)C. The materials are the following: (i) pure BC materials (soot, two chars), (ii) environmental BC matrices (aerosol, marine sediment, two soils, river filtrate), (iii) materials from parent rock (shale, two coals) and (iv) a specific negative control (melanoidin), which is not supposed to contain any BC.

Most of the reference materials were obtained through (standard material) suppliers. The wood char, rice char and melanoidin were produced by us. No commercial standards for these materials are available. The wood and grass char was produced by pyrolysis to simulate natural conditions in a burning log. The starting materials for the wood and rice char were also chemically analysed.

The reference materials come from diverse environments, with large variations in C values, ranging from 2 % for the Chernozem to 90 % for the soot. The standard materials had H/C and O/C ratios within the typical range for these materials given in literature. This elemental data is supported by the CP and BD NMR analysis done on the materials. The \(^{13}\)C CP an BD MAS spectra for the Vertisol and Chernozem are dominated by signals in the aryl C region, typical for charred organic matter.

Not all reference materials were specifically representative of natural samples (soot and char materials). Diesel soot could be considered for future study concerning methodological constraints with highly impure samples containing BC.

The char material lack at least two characteristics common for chars produced under natural conditions, e.g. large \(^{13}\)C isotopic changes during charring and presence of levoglucosan, formed from partly combusted biomass. However, they conformed to other criteria including homogeneity, long-term availability and ease of preparation, which are also important when calibrating methods for BC analysis.
Lignin degradation in soils:

What are the effects of organic matter input, soil pH and nitrogen level?

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Lignin is a cell wall component of vascular plants thought to be relatively stable to decomposition. This makes lignin a major component of the terrestrial carbon cycle. Previous research suggests that lignin turnover is faster than bulk C turnover, both in arable soils and grassland soils (Heim and Schmidt, 2005). It remains unknown how environmental factors affect lignin degradation. In our study we examine the impact of the factors i) organic matter input, ii) soil pH and iii) nitrogen level on lignin degradation. Lignin monomers are released through alkaline CuO-oxidation, and subsequently identified and quantified using gas chromatography-mass spectrometry (GC-MS). Individual compounds are then analyzed for $^{13}$C with gas chromatography-combustion-isotope ratio mass spectrometry. (GC-C-IRMS) (Goñi and Eglinton, 1996).

Soil samples examined in our study are from a time series of arable soils under continuous silage maize with maize residues incorporated or removed (Kristiansen et al., 2005). The plant derived organic matter input was naturally labeled with $^{13}$C isotopes by change from C3 (wheat, average $d^{13}$C $-27\%$) to C4 (maize, average $d^{13}$C $-13\%$) vegetation. A second set of soil samples is from model forest plots, soils being acidic loam (pH 4.1) and calcareous sand (pH 7.2). Treatments were low N deposition (0.5 – 0.7 g N m$^{-2}$ a$^{-1}$) or high N deposition 5 – 7 g N m$^{-2}$ a$^{-1}$). Isotopic labeling originated from addition of $^{13}$C depleted CO$_2$ (Hagedorn et al., 2003). First results on the impact of organic matter on lignin degradation in arable soil will be acquired in November. Determining of how environmental variables affect lignin degradation could further improve C storage models and the management of carbon turnover in soils.

REFERENCES


How do drought and heat affect carbon and nitrogen dynamics in grassland soils?


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A very high percentage of the agricultural land in Switzerland is covered by grasslands (around 70%; Schweiz. Bundesamt für Statistik 2003). Any change in climatic conditions will impact ecosystem functioning and therefore the provision of ecosystem services to society.

Results obtained during phase 1 of the NCCR Climate and also by other research groups worldwide, suggest that – besides an increase in mean air temperature – temperature variability will increase considerably in Central Europe (Schär et al. 2004). However the response of entire grassland systems to drought and heat remains unclear. Many earlier studies focused only on soil or vegetation (e.g. Pfisterer & Schmid 2002) but did not consider the entire ecosystem with its interactions between different ecosystem components. There is little knowledge about how climatic factors affect above- and below-ground processes in temperate grasslands and how to implement potentially safe management strategies to mitigate changes. Thus, project PLANT/SOIL, which is newly established for NCCR Phase 2, will focus on drought and heat effects on managed grasslands. It is based on the findings mentioned above, on questions raised during NCCR Phase 1 and on the expertise of the research groups becoming additionally involved in phase 2.

In grasslands, much of the biological activity and biomass turnover happens below-ground; here carbon stocks can be as large as the annual above-ground harvested biomass. Plant biomass above the cutting/grazing height (typically 3 – 7 cm above ground) is important for agricultural purposes. Biomass below this height is relevant for the fate of carbon, nitrogen and other nutrients in the soil (Avice et al. 1996). The transfer rate for carbon from above-ground litter to below-ground soil organic matter and the release as dissolved organic carbon (DOC) and CO₂ is so far poorly quantified and thus a key issue in this context (Lal 2004). In addition, all these processes are influenced by climatic and environmental conditions. For example, drought conditions in grasslands of varying species richness did not affect above-ground productivity but increased below-ground productivity (Kahmen et al. 2004).

Thus, the project PLANT/SOIL takes up urgent tasks, also pointed out during the IPCC meeting on terrestrial carbon stocks (IPCC 2003), including among other things a) factoring out effects causing carbon stock changes, b) employing high-technology measurements, e.g. isotope tracers, molecular markers, and c) elucidating soil mechanisms in addition to measuring fluxes. Especially aspects b) and c) and the effects of drought and heat are considered for this project.

EXPERIMENTAL APPROACH

The effects of drought on representative grasslands at various altitudes in Switzerland (400, 1000 and 1900-2600 m above sea level) will be studied in field experiments to understand the response of key processes to changed climatic conditions and to provide relevant input parameters needed for simulations. Three research groups will contribute to a comprehensive analysis of the plant/soil/atmosphere system. We use two experimental approaches in this study, 1) field manipulations, and 2) studies in growth chambers. While drought effects on grasslands can be investigated in the field, heat or combined drought and heat effects can only be addressed in growth chambers if soil disturbance is to be avoided and an increase of more than 1 or 2 °C is requested. Two chambers are available at FAL Reckenholz and will be used for detailed studies. Rainfall shelters are used to introduce artificial drought on managed meadows and pastures. The
field experiments are situated along an altitudinal gradient at three ETH research stations, representing Swiss grasslands. We study the effect of drought on ecosystem functioning (e.g. transfer from litter to the soil, partitioning of soil respiration into activities of plants and organisms using stable isotopes) and ecosystem services. We monitor soil microclimate and soil characteristics (including molecular markers, e.g. lignin) as response to drought. The application of stable isotope tracers, i.e., $^{13}$C (as previously labelled biomass) and $^{15}$N (as nitrate) will allow us a deeper insight into the carbon and nitrogen dynamics of plant and soil components of these grassland communities and to distinguish between the respiration of below-ground plant parts and that of microorganisms.

EXPERIMENTAL DESIGN AND INSTALLATIONS

The field experiments are located on grasslands at three ETH research stations in Chamau (400 m above sea level), Früebüel (1000 m) and Alp Weissenstein (1900-2600 m). Rainfall shelters (3 x 3.5 m) are used to generate drought periods. Ten plots were laid out at each location: five plots were equipped with rainfall shelters (to reduce water supply), and five plots were used as control (with ambient precipitation). The rainfall shelters will be installed for a defined period of time. Measurements and sampling for analyses of DOC/$^{13}$C, $^{13}$CO$_2$ and $^{15}$N values will be made 12 times in biweekly intervals. Data will be collected at least during two growing seasons.

To follow the fate of decomposing biomass in the gaseous ($^{13}$CO$_2$), liquid (DO$^{13}$C) and solid soil organic carbon (SO$^{13}$C) phase, we will establish one mesh-covered container (40 cm x 40 cm) supplied with a zero tension lysimeter (15 cm x 15 cm), one PVC-ring ($\varnothing$ 20 cm x 5 cm) and two suction plates ($\varnothing$ 55 mm, at 1 cm and 2 cm depth) on each of the 36 plots (3 locations, 2 treatments (dry/wet), 2 samples (labelled/not labelled biomass), 3 replicates). 18 of these containers will be filled with $^{13}$C-labelled and 18 with unlabelled plant material. For this purpose several kilograms of $^{13}$C-labelled biomass (Lolium perenne and Trifolium repens), differing about 10% from reference material, is available from the Eschikon FACE experiment.

The growth chamber experiments are planned for the third year of the study. The analytical techniques will basically be the same as for the field experiments.

REFERENCES


The CARBOLAKE project:

Europe’s natural lakes as a source of carbon to the atmosphere

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The CARBOLAKE project quantifies the role of lakes and reservoirs within the global carbon cycle, in a first step on the European scale. Many lakes are oversaturated in CO$_2$ with respect to the atmosphere. In contrast lake sediments contain high amounts of carbon that is withdrawn from the atmosphere for a presumable long time.

Carbon dioxide concentrations in the surface water of lakes were calculated from pH, dissolved inorganic carbon or acid neutralizing capacity. Available measurements of fluxes or concentrations were added from the literature. Potential fluxes were calculated for an average wind speed of 3 m s$^{-1}$. Data from 3637 water samples (3030 lakes and reservoirs) were checked for potential CO$_2$ emission. Values range from -37 to 2191 mmol m$^{-2}$ d$^{-1}$ with a mean of 104 mmol m$^{-2}$ d$^{-1}$ or about $450$ g C m$^{-2}$ a$^{-1}$. 85% of the samples were oversaturated with respect to the atmosphere.

Long term carbon burial was evaluated from published studies. Carbon sedimentation data are now available for 144 lakes with Carbon accumulation rates up to 55 g m$^{-2}$ a$^{-1}$. The mean rate was only about 3 g m$^{-2}$a$^{-1}$. European lakes are dominated by boreal lakes without significant carbonate precipitation. Organic carbon sedimentation usually does not exceed 10 g C m$^{-2}$ a$^{-1}$. Until now the sedimentation dataset is not representative and does not include reservoirs which have assumed very high carbon accumulation rates.

In conclusion most naturally lakes act as carbon sources. The annual carbon emission of naturally lakes largely exceeds the storage in the sediment. The estimated net loss is about $70*10^{12}$ g per year. This rate is similar to the emission from European estuaries estimated by Frankignoulle and coworkers.

During the ongoing investigation the dataset will be extended, particularly for reservoir sedimentation. Further analyses including environmental influences will give a better understanding of the control factors leading to a complete carbon budget of Europe’s lakes and reservoirs.

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Impact of variable clover/grass fraction in managed pastures on soil organic carbon under climate change

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Global climate scenarios predict increasing temperature (T) and atmospheric CO₂-concentrations (CO₂) during the coming decades. As grasslands are one of the major biomes and terrestrial soil organic carbon (SOC) reservoirs worldwide, their potential for carbon (C) sequestration becomes one of the possibilities to partly mitigate the increase in CO₂ and should therefore be evaluated.

The build-up or decomposition of SOC is strongly determined by past and present climate, land-use and management. SOC accumulation is the result of the transfer of organic C from the plant litter to light soil fractions (with decadal turnover) and further into more stable fractions (with centennial turnover). As the litter generation depends on the above/below ground biomass production the effects of changing T and CO₂ on productivity influence the build-up of SOC. Model experiments revealed that elevated CO₂ enriches the organic matter in plants and soils with C and leads to increased SOC (Thornley et al., 2000).

Legumes are known to have a major impact on the productivity of grass swards. Field experiments demonstrated that clover has a higher temperature demand than grass and that the symbiotic N₂-fixation of clover is increased to meet higher N-requirements at elevated CO₂ (Zanetti et al., 1996). Thus the ability of legumes to symbiotically fix nitrogen (N) and transfer it to the companion grass may help producing sufficient biomass during a period of N-limitation in mixed swards exposed to elevated CO₂. By enhancing litter production, legumes may therefore substantially contribute to C-sequestration in grasslands (Fisher et al., 1994). Given these facts, the appropriate management of the sward composition appears to be a major option for maintaining or even increasing C-sequestration in meadows and pastures under future climatic conditions.

In most grassland ecosystem models, including the Pasture Simulation Model PASIM (Riedo et al., 1998), the fraction of legumes (namely clover) in the sward (f) is treated as a constant. While it would be desirable to have a time-variable f, sensitivity experiments revealing the effects of f on SOC can nevertheless be performed with the current generation of models. More specifically, our aim is to quantify the impact of varying clover/grass fractions on SOC-development under climate change (CC) using PASIM. The model has already been applied to study the effect of elevated CO₂ on net primary production and carbon stocks in alpine meadows (Riedo et al., 2001).

The model simulates dry matter production (vegetative and reproductive growth) and C-, N- and energy fluxes in hourly time steps. Conceptually, plant litter is partitioned into a structural and a metabolic pool. Further, the model considers three conceptual soil C-pools: an active pool with a turnover-rate of k=3-5 y⁻¹; a slow pool, characterized by k=20-40 y⁻¹; and a passive pool, having k=1000 y⁻¹.

For the present experiment, we refer to our experimental site in Oensingen (450 masl., Kt. Solothurn, Switzerland). We generated meteorological and management data, combined with two scenarios for linearly rising T (from 0 to +2°K) and CO₂ (from 365 to 450 ppm) over the course of 30 years. This gave the following scenarios: R, a reference scenario with constant T and CO₂; S1, a scenario with a linear T-increase of +0.066°K y⁻¹; S2, a scenario with linearly rising CO₂ (+2.83 ppm y⁻¹); and S3, a combination of S1 and S2. For each of the scenarios three fractions of clover were specified: 20%, 40% and 60%. All runs were started from the same equilibrium conditions (SOC = 5.9 kg m⁻²).
The relative changes between the simulated SOC-stocks after 30 years and at equilibrium conditions (Tab. 1) indicate that:

1. Increasing T had a smaller impact on the accumulation of SOC than CO₂, independently of the clover/grass fraction. The scenarios R and S1 produced similar SOC-stocks while the scenarios S2 and S3 led to markedly higher SOC accumulations. Hence, C was preferably sequestered under elevated CO₂ than elevated T environments in a mixed grass-clover sward.

2. Accumulations of SOC gradually increased with rising clover/grass fractions, from 0 to 3% for f=20%, from 7 to 11% for f=40%, and further from 11 to 15% for f=60%. The larger differences in the SOC-accumulations for f=20% and f=40% compared with the smaller differences for f=40% and f=60% suggest a threshold of f=30-40% above which C-sequestration noticeably increased.

Table 1. Percentual changes in SOC-stocks after 30 years of simulations with the scenarios R, S1, S2 and S3 for different f relative to the equilibrium conditions of 5.9 kg SOC m⁻².

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<th>R</th>
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<td>60%</td>
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Our sensitivity experiment suggests that maintaining an adequate average fraction of legumes through management in temperate grasslands is pivotal for stimulating carbon sequestration. However, further experiments with a new generation of models allowing for a seasonally varying fraction of legumes will be needed to confirm the present findings.

REFERENCES


Southern Switzerland forests are dominated by sweet chestnut trees (Castanea sativa Mill.), that grow on characteristically dark soils, rich in humus which overlay acid bedrock. These soils are essentially podzols, but because their eluvial horizon is masked by the overall dark soil colour, they are called cryptopodzols.

The aim of this work is to fathom which processes lead to the stabilisation of organic matter in cryptopodzols and which roles C. sativa and fire play therein.

The stabilisation of organic matter in the examined cryptopodzols comes about through different processes, whereby the following two dominate. The high concentrations of aluminium in the acid bedrock favour the formation of stable aluminium-humus complexes. Blaser et al. (1987) reasoned that these complexes are the chief cause for humus enrichment in these soils. However, the results of this study indicate that it is not the only cause. The high number of charcoal pieces found in the soil and the black carbon values measured, suggest that a part of the carbon is stabilised by the chemical binding of pyrogenic (black) carbon. The density separation results, which indicates different types of carbon bonding, supports this argument. The hypothesis that the high phenol contents of sweet chestnut litter that builds stable chelate complexes is responsible for a large part for the humus enrichment, could not be confirmed.

The colorimetry data of the soils show a decrease in lightness with increasing organic carbon and black carbon. Considering the fact that the density fraction containing black carbon is also the darkest one, leads to the conclusion that the characteristic dark colour of the cryptopodzols is caused by pyrogenic carbon.

The charcoal analysis shows that Castanea sativa Mill. was already present in southern Switzerland 3000 years ago (at least local) and was not introduced by the Romans as is currently the thought (Burga, 1988; Gobet et al., 2000; Tinner und Conedera, 1995; Zoller, 1960). The dated charcoal pieces of white fir (Abies alba Mill.) confirm its retraction 3000 to 4000 years ago from colline sites in southern Switzerland. The fact that the ages of charcoal pieces did not increase with profile depth in all cases points to rearrangement processes in soil. From the amounts of charcoal and theirs ages it emanates that fire has played an important role in the vegetation history of southern Switzerland since the onset of the Holocene more than 7000 years ago.

REFERENCES


Investigation of organic matter decomposition in a groundwater enrichment site

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In the city of Basel drinking water is mainly gained by infiltrating water from the river Rhein into a natural floodplain area. This natural filter system enhances water quality in a very efficient way, thus reducing efforts and costs of drinking water purification.

Water from the river Rhein is used for groundwater enrichment. After soil infiltration and aquifer passage, the water is discharged by several wells downstream. During the underground passage most of the dissolved organic carbon (DOC) is sequestrated (Rüetschi 2004). For future use of the system the question has to be answered if the main purification process is simple adsorption in the aquifer (which might eventually lead to clogging of pore space) or if substantial biological degradation occurs. To investigate the systems dynamic stable isotope ratios as well as soil gas measurements and sorption experiments in the different soil and aquifer compartments are carried out.

SITE DESCRIPTION

The aquifer consists mainly of fluvial gravel and sand, deposited by the rivers Wiese (Blackforest, silicates) and Rhein (Alpes, carbonates and silicates). Oxic and reducing conditions alternate in several horizons in interbedded strata. Floodplain soils of varying thickness from 30 to 100 cm overlay the aquifer. Natural flooding is prevented at the site since drinking water production gained priority during the past 80 years. Total water balance is 1200 l*s⁻¹, artificial infiltration 720 l*s⁻¹ and discharge for drinking water production 670 l*s⁻¹ (Zechner 1996).

FIRST MEASUREMENTS

Soil gas measurements from 4 m below surface show high methane and carbon dioxide concentrations indicating decomposition of organic matter under reducing conditions. Soil organic carbon content outside one infiltration field decreases with depth whereas inorganic carbon content increases. Preliminary measurements of $^{13}$C signature of soil gas indicate a decrease with depth. The latter result points to continuous organic matter decomposition even in deeper horizons. Further investigation of DOC and soil $^{13}$C signatures are in progress.

FURTHER STEPS

To verify carbon fluxes and sorption a soil column experiment is planned. Columns will be fed with the same water as used for infiltration, in- and outflow, gas and soil will be analysed for carbon and $^{13}$C.

REFERENCES

Bi-directional exchange of N₂O between the atmosphere and the soil in agricultural systems


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The project aims to improve the understanding of the turnover of N₂O in agricultural soil by measuring gross production and uptake of N₂O within the soil profile. Various mechanisms by which N₂O can be consumed will be investigated regarding their relative importance in a natural environment. The overall hypotheses are that a large fraction of the gross production of N₂O is consumed before it is emitted to the atmosphere. Consumption is hypothesized to be a biological process with a first order kinetics.

The project combines field measurements and laboratory studies to describe production and uptake rates of N₂O. For the field study we focus on managed grassland systems at two sites that have been built-up in other European projects and are ideally suited for this purpose. Both sites are equipped with permeable membrane tube systems (METT) that allow continuous measurements of soil profile concentration in the open pore space of the soil. The continuous survey of the N₂O concentration in the soil down to a depth of 50cm below surface allows selecting time intervals showing e.g. strong emissions or uptake for detailed laboratory studies to determine production and uptake rates.

Thus the field sites will provide samples for laboratory analysis in which gross production and uptake rates will be measured in a controlled environment where moisture, temperature and N₂O concentration in the surrounding atmosphere are modified. Studies with labelled ¹⁵N₂O will allow following the fate of N₂O-N through the uptake process.

Field experiments have shown intermittent periods of enhanced N₂O concentrations in the soil which were not accompanied by N₂O emission from the soil surface. Such observation can only be explained by N₂O being consumed within the soil profile before being able to reach the surface.

First experiments in the laboratory were to expose samples to varying N₂O concentrations and analysing the correlation between net exchange and N₂O concentration. Tests with various O₂ concentrations, temperature, sample size and amount were accomplished. The results of these first experiments showed some interesting connection between the N₂O production and changed parameters.