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17.1

Forest growth in Switzerland during the hot summer 2015

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In 2015, Switzerland experienced the second warmest summer since measurement start in 1865. Temperatures were 2.4°C higher on average and precipitation amounts were regionally below average (norm period 1981-2010) (MeteoSchweiz 2015). Hence, the hot summer 2015 was a prime example for summers as projected under future climatic conditions in Switzerland (CH2011 2011). Since forests cover about one third of Switzerland, the response of forest ecosystems to such extreme events is of high interest for carbon balance, yield and finally ecosystem stability. Thus, how did trees in Switzerland experience the hot summer 2015?

Investigating such questions is what the research network TreeNet is aiming at. It uses point dendrometers to continuously measure fluctuations of stem radius on the micrometer scale. In our study, we analyzed tree growth from 56 trees across Switzerland, originating from 11 sites. The majority of the trees analyzed were Picea abies and Fagus sylvatica (the two main tree species in Switzerland), but also Abies alba, Fraxinus excelsior and Quercus species were included. The high temporal resolution of our measurements not only allowed deriving annual tree growth, but also, as a novel approach, to exactly define tree-specific growing periods. As a next step, we could then characterize the meteorological conditions for each tree during its growing period. We then finally compared our results to the year 2014 where, in contrast to 2015, the summer was relatively cool and wet.

At many sites the hot summer 2015 lead to reduced tree growth in comparison to 2014. This effect was strongest for Picea abies which showed decreased growth at 5 of 6 sites and the highest growth differences between 2015 and 2014 among all species investigated. The difference was highest at lowland sites, while it was less strong or even positive at higher altitude sites. The pattern was less clear for the other species investigated, because both increased or decreased growth was observed in 2015 in comparison to 2014. Thereby, especially for Fagus sylvatica, trees that experienced less drought stress during the growing period (e.g. due to locally small precipitation deficits or high water holding capacities of the soil) could partly profit from the hot summer 2015 and grew slightly better in comparison to 2014.

By integrating the response of tree growth to the hot summer 2015 from numerous trees and sites across Switzerland, we received an impression of how Swiss forest ecosystems might respond to more extreme summers projected under future climate.

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Carbon budgets of six different agricultural crops at the Oensingen arable land Fluxnet site

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The arable land Swiss Fluxnet site at Oensingen, Solothurn (CH-Oe2) has been running since December 2003. This site provides unique data to study turbulent fluxes of carbon dioxide, water vapour and energy as well as crop yield, carbon budgets and microclimate in a typical Swiss crop production region on the Swiss Plateau. It is the only long-term Swiss Fluxnet arable land site and it belongs to the longest continuously running arable land flux sites worldwide.

The site is managed under the low pesticide integrated production (IP) farming protocol with a crop rotation focusing on winter wheat, which also includes winter barley, rapeseed, peas, potatoes and intermediate cover crops. Long-term measurements at the site include eddy covariance measurements of three-dimensional wind velocity, air temperature, carbon dioxide and water vapour concentrations as well as soil temperature, soil moisture, soil heat flux, relative humidity, incoming and outgoing short and longwave radiation and incoming photosynthetically active radiation. Additionally, management information, harvested crop and straw yields as well as carbon and nitrogen concentrations of yield and residue are available.

This study uses this rich dataset to address the following objectives:

1. To quantify the carbon budgets of the different crop types planted at CH-Oe2 in the past thirteen seasons,
2. To determine the interannual variability in the carbon budgets of winter wheat, winter barley and rapeseed,
3. To analyze the climatic conditions at the site during these thirteen seasons and compare them to the carbon budgets.
17.3

Management matters: Testing a mitigation strategy of nitrous oxide emissions on managed grassland

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The magnitude of greenhouse gas (GHG) exchange between managed grasslands and the atmosphere largely depends on management practices. While natural or extensively managed grasslands are known to function as GHG sinks intensively managed grasslands are often characterized by substantial nitrous oxide (N₂O) emissions and therefore act as net GHG emitters. One potential approach to mitigate N₂O emissions is a decrease in fertilizer inputs by replacing the needed N input by biological nitrogen fixation via legumes. However, the effect of legumes on nitrous oxide fluxes is still uncertain. In this study we aim at quantifying net GHG fluxes from two management strategies under field conditions in relation to the productivity of the fields (yield estimates). Furthermore, we aim at revealing direct drivers of N₂O exchange and developing suggestions for a more sustainable grassland management in the future.

We conducted an ecosystem-scale experiment to compare GHG fluxes from an intensively managed Swiss grassland site. The experimental approach consisted of a control parcel representing conventional management with up to 6 harvests and subsequent organic fertilizer application (N input 310 kg ha⁻¹ yr⁻¹) as well as an adjacent treatment parcel where common organic fertilizer N inputs are replaced by biological nitrogen fixation via legumes. We measured the net exchange of the three major GHGs, nitrous oxide (N₂O), methane (CH₄) and carbon dioxide (CO₂) with the eddy covariance technique in 2015. GHG flux measurements were accompanied by measurements of commonly known driver variables such as water filled pore space, soil temperature, soil oxygen concentrations and mineral N to disentangle the soil meteorological influence of N₂O fluxes from human drivers.

We measured enlarged N₂O fluxes following organic fertilizer application in the control site and unchanged N₂O emissions in the treatment site. We also observed peaks in N₂O emissions on the treatment parcel, which partly could be attributed to rain events. Net annual fluxes were about one third lower at the experimental parcel. Annual yields were 19% lower at the experimental parcel compared to the control parcel. Relatively dry conditions during the growing season affected plant growth and the timing of the management events.

Significantly lower nitrous oxide fluxes under experimental management compared to conventional management indicate that nitrous oxide emissions can be effectively reduced at very low costs with a clover-based management. Dry weather conditions are regarded as adequate to reflect future climate at the site. In order to get insights into effects under more common (i.e. wetter) weather conditions and into long-term effects, further measurements are required.
17.4

The influence of ground surfaces on urban climate

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INTRODUCTION.

In the context of global climate change the term urban heat island (UHI) is a phenomenon that has been observed in recent years (Oke 1982). UHI have a negative influence on the water cycle and on human health. Within the same city important differences in temperature can be observed. These differences depend to a high degree on the type of ground surface (e.g. impermeable and permeable surfaces, waterbodies, parks, etc.) (Kustas 2000).

The goals of the project THER-SOL were to 1. Categorize significant types of urban ground surfaces, 2. Quantify the impact of the identified surface types on urban microclimate, 3. Identify strategies to decrease the appearance of UHI through the identification of potential surfaces where the type of surface can be changed.

STUDY SETTING.

The sectors Mail-Jonction and Acacias in the city of Geneva had been chosen. Within the limits of these sectors different types of impermeable and permeable surfaces can be found. Compared to other Swiss cities the city of Geneva is rather flat and less subjected to the influence of the relief, which may allow for an extrapolation of the results to other cities. Furthermore a rich collection of geographical data layers (e.g. surface types, solar radiation, etc.) is publicly available (SGOI 2016).

In the middle of the two sectors, within the uncovered Plainpalais-area, three very different surface types were identified. On these three sites experimental stations were set-up to measure different energy fluxes between the atmosphere and the surface (see Figure 1). Thermocouples and thermometers were placed at 8 cm depth to evaluate heat flux in the soil and at 3 m height to evaluate sensible heat flux and net radiation. Data was collected during ten consecutive days in summer 2015.

Figure 1: Experimental setup at Plainpalais: lawn (green dot on the map; 2nd picture), ghorr/Beaujolais-gravel (red dot; 3rd picture) and asphalt (blue dot; 4th picture).

RESULTS.

Significant differences were identified between the three surfaces. Sensible heat was slightly higher for the gravel-surface than for the lawn. The heat flux in the soil was more reactive on the gravel that warms up and cools down faster. Net radiation is significantly higher on the lawn, where more energy is transformed even if the gravel is darker than the lawn. This evidence suggests that permeable surfaces help decreasing heat in urban areas. Additional measures made with a backpack equipped with thermometers enabled us to quantify the thermal comfort experienced by citizens and to highlight that the areas covered by vegetation indeed are important in the context of UHI. Based on the available land-use layers we identified current permeable surfaces. We calculated that only 4% of the total surface are currently covered by vegetation (see Figure 2; 1st map). By transforming existing surfaces, such as roads, car parks, crossroads, pavements and tram tracks, an estimated 9-10% of the total surface of the study area could be made permeable.(see Figure 2; 2nd map).
CONCLUSIONS AND PERSPECTIVES.
This project demonstrated the significance of permeable surfaces regarding UHI. The Plainpalais area is an interesting area since very different surface types can be found here. According to our results, the ideal surface has a high soil retention capacity (storage). The cooling potential of a surface is mainly linked to its evaporation potential. It would be interesting to consider the influence of trees on UHI as well. Another possibility is to analyze the orientation and the shape of urban canyons in order to refine the results. Finally as this project focused on lawn, gravel and asphalt, it would be interesting to include other ground surface types as well.

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17.5

Process-based crop model simulations of carbon fluxes and stocks – an evaluation at the Oensingen cropland site

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In response to climate change mitigation strategies and food security, there is an ever-increasing requirement to understand the key drivers of the cropland carbon (C) balance. Croplands are also entirely managed ecosystems, which causes uncertainty when investigating the impacts of climate on crop growth.

Process-based crop models, driven by meteorological observations, can provide a realistic simulation and diagnosis of the variability in land-atmosphere C fluxes and yield. However, the amount of field-scale observations that are required to thoroughly assess, and subsequently improve, the accuracy of crop models are typically spatially and temporally sparse.

This research evaluates the performance of the Soil-Plant-Atmosphere Crop (SPA-Crop, Sus et al., 2010) model for the simulation of daily C fluxes and stocks of multiple crop types and seasons. SPA-Crop is a detailed model, simulating ecosystem photosynthesis and water balance at fine temporal (half-hourly time-steps) and spatial scales (multiple canopy and soil layers). We first initialise the model using management information and continuous meteorological observations that are available during 10 crop growing seasons (including wheat, barley, rapeseed and pea) at a cropland site located in Oensingen, Switzerland. Second, we evaluate the daily and at-harvest cumulative model estimates of photosynthesis and net ecosystem exchanges (NEE) of C using data derived from field-scale eddy covariance measurements. Further comparisons are made between the modelled and observed yields.

Across all crop seasons we demonstrate a high agreement between the observed and modelled photosynthesis (mean $R^2 > 0.70$ and RMSE < 2.0 gC m\(^{-2}\) day\(^{-1}\)). A similarly high accuracy is shown for the NEE (mean $R^2 > 0.65$ and RMSE < 1.5 gC m\(^{-2}\) day\(^{-1}\)). Overall SPA-Crop underestimated the crop yield by around 10%.

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17.6
Volcanism, climate and human: On an illuminative journey with an ice-core time machine.

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By using state-of-the art absolute and relative dating techniques and integrating information from ice cores, tree-rings and documentary records we developed a new timeline of volcanic eruptions and their aerosol forcing on climate for the past 2,500 years (Sigl et al., 2014, 2015, 2016). Ice-core composite records of sulphur from Greenland and Antarctica form the backbone of the reconstruction.

Here, we report the timing and consequences of two of the greatest volcanic episodes of the past two millennia: the so-called ‘Millennium Eruption’ of Changbaishan and the lava flood eruption of Eldgjá (Iceland). The Millennium Eruption (946 AD) was a large explosive episode, comparable to that of Tambora (Indonesia) in 1815, which is associated with the following “Year without a summer”. The Eldgjá event (939 AD), on the other hand, was a flood lava eruption, comparable to but somewhat larger than that of Laki in 1783/84.

In 536 AD, observers in Europe documented a mysterious cloud which dimmed the light of the sun for at least a year. Using a coupled aerosol-climate model, with eruption parameters constrained by our re-dated ice-core records and historical observations of the aerosol cloud, we reconstructed the radiative forcing resulting from a sequence of two major volcanic eruptions in 536 and 540 AD (Toohey et al., 2016). We estimate that the decadal-scale Northern Hemisphere (NH) radiative forcing from this volcanic “double event” was larger than that of any period in the past 2,000 years. Earth system model simulations including the volcanic forcing show peak NH mean temperature anomalies reaching more than −2 °C. Tree-ring records from Eurasia demonstrate the sudden and prolonged cooling, which took place in the beginning of the 6th century and which continued to characterize the period until around 660 AD. We thus identify the interval from 536 to about 660 AD as the Late Antique Little Ice Age (Büntgen et al., 2016). Spanning most of the NH, we suggest that this cold phase be considered as an additional factor contributing to the establishment of the Justinian plague, and transformation of the eastern Roman Empire.

We further integrate written and natural archives to show that volcanic eruptions repeatedly suppressed the agriculturally-critical Nile flood. Previous work linking eruptions to Nile flow noted coincidences in timing between Nile “failure” and a handful of historic eruptions. Using our new ice-core volcanic reconstruction with Nilometer data (the world’s longest documentary hydrological record) and qualitative flood descriptions during the Ptolemaic Era (261 to 30 BCE), we show a persistent suppression of the Nile across more than a millennium.

These examples demonstrate the sensitivity of the climate system and vulnerability of human societies to large volcanic eruptions – both major themes of a new PAGES Working Group “Volcanic Impact on Climate and Society, VICS”. Aerosol properties derived from this new ice-core based volcanic reconstruction will be employed as the default volcanic forcing series for performing transient climate model simulations of the past 1,000 and 2,000 years within the Paleoclimate Modelling Intercomparison Project (PMIP4). This will help to further improve our understanding of the volcanic influences on global and regional climate, at various temporal scales.
Figure 1. (Left) Greenland volcanic sulphate deposition and Northern Hemisphere June-August temperatures from 530-580 AD marking the onset of the Late Antique Little Ice Age; (right) satellite image of the caldera from the Ilopango eruption, one of the candidate events for the large 540 AD ice-core sulphate signal.

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Büntgen, U. et al. 2016: Cooling and societal change during the Late Antique Little Ice Age from 536 to around 660 AD. Nature Geoscience 9, 231–236.
Soil carbon dynamics and fluxes across a climatic gradient from temporally-resolved radiocarbon measurements

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Soil organic matter (SOM) constitutes the largest terrestrial reservoir of organic carbon, and therefore quantifying soil organic matter dynamics (carbon turnover, stocks and fluxes to the atmosphere) across spatial and climatic gradients is essential for an understanding of the carbon cycle and the impacts of global change. Links between soil carbon dynamics and different climatic and compositional factors are particularly poorly understood. Radiocarbon constitutes a powerful tool for unraveling soil carbon dynamics and is increasingly used in studies of carbon turnover. Temporally-resolved radiocarbon measurements, which take advantage of "bomb-radiocarbon"-driven changes in atmospheric 14C over the last decades, enable further constraints to be placed on C turnover times. These in turn can yield more precise flux estimates for both upper and deeper soil horizons. This project combines bulk radiocarbon measurements on a suite of soil profiles spanning strong climatic (MAT 1.3-9.2 °C, MAP ~600 to 2100 mm m$^{-2}$y$^{-1}$) and geologic gradients with a more in-depth approach for a subset of locations. For this subset, temporal and carbon-fraction specific radiocarbon data has been acquired for both topsoil and deeper soils. These well-studied sites are part of the Long-Term Forest Ecosystem Research (LWF) program of the Swiss Federal Institute for Forest, Snow and Landscape research (WSL). Resulting temporally-resolved turnover estimates are coupled to carbon stocks, fluxes across this wide range of forest ecosystems and are examined in the context of environmental drivers (temperature, precipitation, primary production and soil moisture) as well as texture (sand, silt and clay content). Statistical analysis on the region-scale – correlating radiocarbon signature with climatic variables such as temperature, precipitation, primary production and elevation – indicates that composition rather than climate is a key driver of Δ14C signatures. Preliminary estimates of carbon turnover, stocks and fluxes derived from temporally-resolved measurements highlight the strong gradients and variability there is in carbon efflux in top- and deep soil in a range of ecosystems. Overall, this study has afforded a uniquely comprehensive dataset that improves our understanding of controls on soil carbon dynamics and carbon fluxes to the atmosphere across spatial and temporal scales, as well as the pool-specific and long-term trends in soil carbon (de)stabilization and vulnerability.
P 17.1

Is grain size distribution an important factor of Oxalate-Carbonate Pathway efficiency?

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Carbonate accumulations through the oxalate-carbonate pathway (OCP) are recently studied in Madagascar around *Tamarindus indica* (Fabaceae). Basically, OCP refers to the transformation of oxalate, a product of photosynthesis, to carbonate into the soil when oxalogenic trees, oxalotrophic bacteria, and fungi combine efficient activities. This process increases local pH and can lead to long-term carbon sequestration when occurring in Ca-carbonate free soils.

Many factors regarding to site conditions could influence the importance of OCP effects on soil such as the tree specie. Grain size distribution with its link to soil permeability may be one of these factors. Do grain size distribution affect the OCP’s efficiency? This study therefore aims at investigate the effect of grain size distribution on soil alkalinization and carbonate accumulations under the influence of an OCP ecosystem.

Consequently, six tamarinds, with a diameter at breast height (i.e. DBH) of at least 65cm and 16 m high, were selected. Three soils profiles were dug around each tree. One soil profile 15 m away was established as a reference profile. Soil samples were taken from six depths in the different soil profiles. Variables such as pH H₂O, grain size distributions, and carbonate detection were performed.

Reference soils data results were used to build a cluster tree using hierarchical cluster analysis highlighting two groups of soils. The first group, represented by three trees is defined as sandy soils with pH ranging from 7 to 7.5. The second group, also constituted by three trees is defined as loamy-sandy, the pH ranging from 6.5 to 7. Considering this discrimination of sites, grain size distribution under trees is assumed to be similar compared to their associated distant soils. The loamy-sandy soils present a pH shift (from assumed original conditions measured at distant sites and soils around the trees) of 1.17±0.31 (n=54) higher than for sandy soils, 0.64±0.58 (n=51) whereas the carbonate detected by X–Ray is less important for loamy–sandy soils (2.9±2.46%, n=46) than sandy soils (1.41±1.14%, n=40). In addition, field observations showed the presence of local carbonate accumulation in deeper horizon of four profiles of sandy soils.

These results suggest that the particles size fractions have somehow their importance in the downward transfer of materials and could favour carbonate accumulation in sandy soils. The higher buffering capacity of the loamy-sandy soils than sandy soils was presumed to counteract the alkalinization process and could explain the pH shift difference.

Nevertheless, the more acidic pH of distant loamy-sandy soils may explain this pH shift difference. As the stability pH for calcite in the present environmental conditions is 8.4, the soil pH increase to allow carbonate to precipitate is much more important in acidic soil than basic soil.

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Stability of soil organic matter in Alpine ecosystems: no relationship with vegetation

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There is an emerging understanding of mechanisms governing soil organic matter (SOM) stability, which is challenging the historical view of carbon persistence¹. According to this alternative vision, SOM stability is not directly regulated by the molecular structure of plant inputs (i.e. the historical view), but the biotic and abiotic conditions of the surrounding environment which play a major role and mediate the influence of compound chemistry. The persistence of SOM is thus influenced by ecological conditions, controlling the access and activity of decomposers’ enzymes and being ecosystem-dependent.

In this study, we investigated differences of (1) carbon content, and (2) stability of organic matter in litter and organomineral layers from the most widespread plant communities at the subalpine-alpine level of the Swiss Alps. For this purpose, 230 samples from 47 soil profiles have been analysed across seven plant communities, along a subalpine–alpine elevation gradient. Both calcareous and siliceous grasslands were studied, as well as snowbed and ridge communities. Aboveground litter and A horizons were sampled and analysed using Rock-Eval Pyrolysis, a proxy-technique commonly used for the investigation of organic matter composition and stability²,³.

Results show that the litter layers of the seven plant communities are significantly different in terms of total organic carbon (TOC) content, but slightly variable in terms of stability. The situation is radically different in the organomineral horizons where the amount of organic carbon is interestingly homogeneous, as well as the SOM stability. In mineral horizons, the amount and stability of SOM are mainly driven by the geological settings, and therefore vary in the different plant communities.

These results show a clear disconnection between organic, organomineral, and mineral horizons in terms of factors governing soil organic matter stability. Consistent with the recent view of the carbon balance, plant input seems to influence the litter C dynamics (qualitatively and quantitatively) but not the SOM stability in A and mineral horizons.

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