Final report

LandScales
Connecting processes and structures driving the landscape carbon dynamics over scales

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Contact partner & project leaders: Prof. Dr. Arthur Gessler (WSL (CH), ZALF) & Dr. Katrin Premke (IGB)

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(1) Executive summary

The Landscales project

1. **The project LandScales** (Connecting processes and structures driving the **land**scape carbon dynamics over **scales**) integrated the aquatic and terrestrial perspectives of landscape carbon dynamics within a multidisciplinary collaborative research environment, by characterising structures, processes, and fluxes across scales. The main focus of the LandScales project was to assess the interlinkage between the terrestrial and aquatic domain with respect to the carbon balance by the interdisciplinary team work of terrestrial and aquatic trained students. We focused mainly on two kettle holes within the moraine landscape of the Uckermark (nearby the villages of Kraatz and Rittgarten), where intensive studies were performed and extrapolated these results by different techniques on the landscape scale.
2. Mechanistic processes of carbon turnover in the kettle holes were assessed by analysing different carbon pool qualities and their availability for the microbial community. This comprised organic matter of terrestrial and aquatic origin. This assessment was completed by isotopic approaches spanning from the soil/sediment aggregate to the landscape level elucidating the origin and metabolic history of the organic carbon. Fluxes od CO_2 between the ecosystem and the atmosphere were assessed with gas exchange chambers in transects from the open water to the reed belt zone. Terrestrial C fluxes in the agricultural landscape were determined via net primary productivity and biomass harvest assessments as well as via a mass balance approach for soil erosion. Moreover, sediment cores in kettle holes were analysed to understand the impact of agriculture. In a modelling approach, the interplay between various state variables of the kettle holes on organic matter turn-over was analysed
3. The main results of our study were that (1) small lakes and ponds with a pronounced emerging macrophyte vegetation will likely more rapidly infill and dry out as mainly photoplankton dominated water bodies due to the different decomposability of the organic matter, (2) that the kettle hole hydroperiod with dry-wet cycle rhythms is an additional central driver of OM turn-over and that also during the water-filled period kettle hole are net emitters of greenhouse gases. Between 35 and 44% of the two kettle hole catchment areas were affected by erosion and approx. 10% of eroded material was transported into the kettle hole and that also pulsed losses by erosion events occur. From a modelling perspective, it is shown that external and internal (via sediment) loadings constitute a fundamental nutrient source for the primary producers in the kettle hole and highlight the potential impact of catchment land-use on the ecological functioning of the pond.
4. The results demonstrate on the one hand that kettle hole biogeochemistry is linked to the land use in the catchment area and inputs from the terrestrial domain. However, large parts of the biogeochemical cycle is driven by kettle hole internal processes and the hydroperiod is one important factor that determines the carbon fluxes in these small water filled depressions.

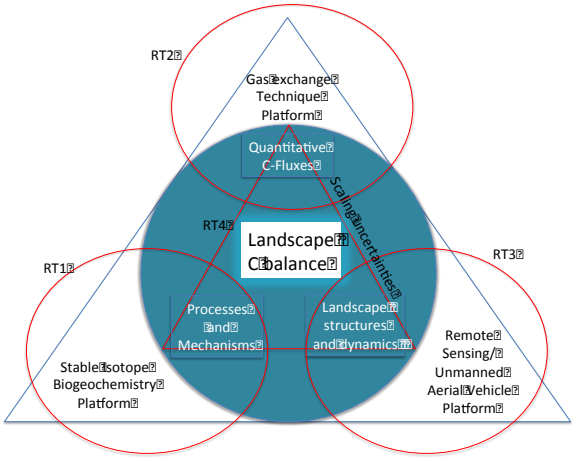
(2) Objective of the project

LandScales (Connecting processes and structures driving the **land**scape carbon dynamics over **scales**) integrated the aquatic and terrestrial perspectives of landscape carbon dynamics within a multidisciplinary collaborative research environment, by characterising structures, processes, and fluxes across scales. The main focus of the LandScales project was the interdisciplinary team work of terrestrial and aquatic trained students as well as investigations of the two kettle holes nearby Kraatz and Rittgarten. To meet this research the two selected kettle holes from the Uckermark region in Brandenburg, Northeastern Germany (Rittgarten: N 53°23'22" E 013°42'09"; and Kraatz: N 53°25'05" E13°39'48") were instrumented for long-term research.

Fig. 1: The 2 instrumented kettle holes Kraatz & Rittgarten.

Both kettle holes are surrounded by an intensely managed agricultural landscape. Instrumentation was done in the year 2013 with weather stations, multiple oxygen sensors in the water, and pH, conductivity, and temperature probe in the water column. Additional a bridge for a good sampling were build. In addition, to these intensively assessed kettle holes, a large number of additional small water bodies within the same catchment were assessed by applying various (e.g. isotopic landscape (isoscape)) approaches to transfer the findings to the landscape scale.

Structure of LandScales. The project was set up in a matrix structure and was subdivided in three core (WP1-3) and one overarching research topics (WP4). They comprised mechanisms (WP1), fluxes (WP2) and structures/erosion (WP3) of the landscape C dynamics and had both a terrestrial and aquatic focus. Each WP was part of the Research Platform (green circle) and the Methods & Infrastructural Platform (blue triangle). The three core WP were interlinked by the assessment of uncertainty in transferring process and fluxes across scales (inner red triangle; WP 4).



Due to its multidisciplinarity LandScales had several goals to meet: Some studies aimed to assess the relative importance of differences in carbon (C) quantity and quality for microbial and biogeochemical processes or quantified the GPP in temperate nutrient-rich kettle holes with different typical vegetation types, for instance. Other tested if hydroperiod and land management were imprinted on the isotopic values ($\delta^{13}C$, $\delta^{15}N$) or used isoscapes to under-

stand the complex land-use and management patterns of the agricultural landscapes (see individual reports of WPs).

Next to the work in situ at the kettle holes additional lab experiments were performed as well as studies abroad at similar systems but different climate. Moreover, the project additionally attracted several scientists who dock on the project and added valuable results for the overall picture.

Not all planned work could be implemented due to problems in finding suitable staff (see WP reports) and due to break off of one PostDoc due to personal problems after 2/3 of the project time. The latter problem was affecting also the overarching goal since this person could have added gas exchange data to the entire picture. The lack of these now incomplete analysed data is an unfortunate drawback for the entire project but could be partially compensated by the implementation of additional approaches such as the isoscapes assessments. However, the very good work of the other project members resulted in now more than 20 already published peer reviewed articles plus additional ones in review, press or in preparation. Thus, the overall goal of the project could be achieved and investigations were all in all very successful.

During the project phase, regular meetings (every second month) were held between all participants and various guests who used the LandScales instrumented kettle holes for further examinations. Additionally the project was observed and reviewed by our advisory board, three internationally leading scientists (Prof. Dr. George Arhonditsis, University of Toronto, Canada; Professor Dr. Mike Billett, University of Stirling, UK; Dr. Bernard Longdoz, INRA, France) who also always participated during the yearly 2 to 3-days workshop in Wrechen, NE Germany.

(3) Presentation of selected results (WP1 to WP4)

WP1 Process and mechanism: Mechanisms regulating the C balance across scales

Katrin Premke, Katrin Attermeyer, Sabine Flury (IGB), Arthur Gessler (WSL, ZALF) Kai Nitzsche (ZALF), Zachary Kayler (ZALF)

WP1 research span from aquatic field measurements over lab experiments to terrestrial field and lab investigations. Following excerpts are presented:
In two separate field studies, the aquatic part of this WP aimed to assess the relative importance of various environmental factors on bacterial and biogeochemical processes in the water column and the sediment of kettle holes.
The sub-project of Sabine Flury et al. was focused on the role of different organic carbon (OC) quality pools for benthic microbial carbon (C) processing. This topic is of particular interest for small, shallow water bodies in agricultural landscapes, e.g. kettle holes. Their OC pools spread along a continuum of different reactivities (i.e. from lignin-rich to lignin-poor OC) and thus availabilities for microbes. Up to 50% of the total gross primary production (GPP) can be produced from emergent macrophytes that are rich in lignin, cellulose and other rather refractory OC compounds. They evaluated potential aerobic mineralization and benthic microbial phospholipid-fatty acid derived biomass in relation to two major OC quality groups ('lignin-rich' vs 'lignin-poor') found in two temperate, nutrient-rich kettle holes during a year. Nutrients and dissolved OC quality seem to affect aerobic C mineralization rates under non O_2 limiting conditions. According to $\delta^{13}C$ mixing models, the 'lignin-poor' OC (i.e. OC produced below the water surface) was the preferred C source for microbial PLFA biomass production throughout the year despite the fact that the 'lignin-rich' OC from e.g. emergent macrophytes, shore-line vegetation and/or soil erosion contributed most to the OC pool in the sed-

iment. This suggests that internally produced 'lignin-poor' OC is exposed to fast turnover while the 'lignin-rich' OC is prone to burial. The results indicate that systems with a primary production dominated by phytoplankton (e.g. large lakes) are more likely to persist as water bodies, while other small lakes and ponds with a pronounced emerging macrophyte vegetation will likely more rapidly infill and dry out. Furthermore, tight feedback loops between the vegetation, physico-chemical parameters (e.g. temperature and O_2) and biogeochemical processes were observed. These results are presented in the manuscript Flury et al. (– L&O, submitted).

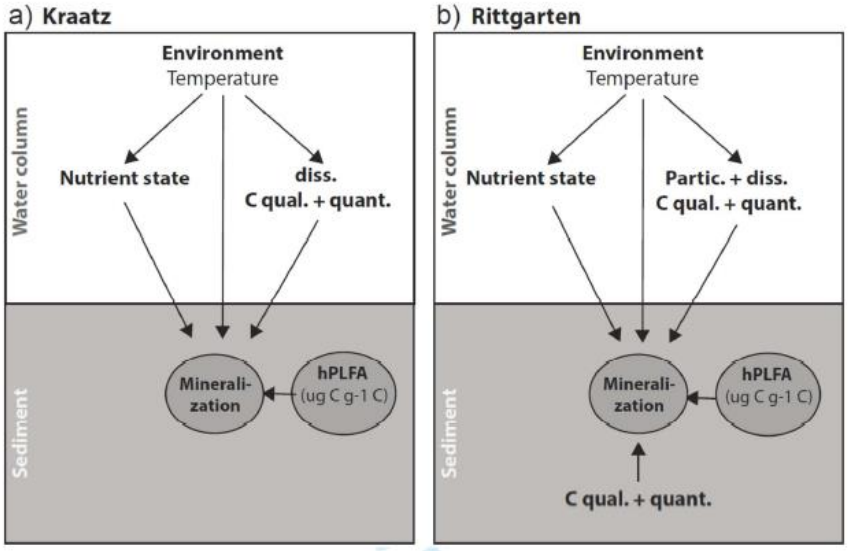


Fig. 2: Conceptual figure of major control mechanisms of potential microbial mineralization and heterotrophic bacterial PLFA (hPLFA) biomass in the two kettle holes based on Kendall's Tau correlation coefficients. Components written in italics means it correlates negatively with the other parameter to which the arrow is pointing. Otherwise the correlation is positive. The presented scheme is simplified and by no means exhaustive, e.g. not showing potential feedback mechanisms.

In another field study by Katrin Attermeyer et al., ten kettle holes were investigated in northeastern Germany and particulate organic carbon and matter served as indicators of autochthonous production and represented the most important parameters to explain variations in bacterial production and community respiration in the water column (Attermeyer et al. 2017).
Moreover, to compare same ecosystems in different climate zones carbon turnover and greenhouse gas emissions from a small (0.6 km^2) water-harvesting lake in South India and the effect of floating macrophytes on these emissions were analyzed during a research stay in India (financed by a DAAD fellowship). The CO_2 and CH_4 emissions from areas covered by water hyacinths were reduced by 57% compared with that of open water. However, the carbon mineralization rates were not significantly different in the water between the two areas. We conclude that the increased invasion of water hyacinths and other floating macrophytes has the potential to change greenhouse gas emissions, a process that might be relevant in regional carbon budgets (Attermeyer et al. 2015).

In another lab-based project which was conducted by Sabine Flury et al. their investigated the effect of bubble-release from cohesive sediments on pore water exchange processes. In this laboratory experiment, large tanks that were filled with sediment were assessed. The sediment was spiked with yeast extract to enhance methane gas formation. Bromide was used to trace pore water exchange at the sediment-water interface. In contrast to expectations, the results showed a strong inhibition of the pore water exchange. The authors propose that the bubbles act as an obstacle for the pore water and thus increase tortuosity. The results are published in Flury et al (2015).
Another experiment in the lab was performed to analyse terrestrial and aquatic carbon and its quality. Attermeyer et al. incubated bacterial communities extracted from four lakes within the LandScales catchment with glucose, a fulvic acid standard and a mixture of both. The consumption of total dissolved organic carbon, low molecular weight substances (LMWS)

and humic substances (HS) were determined in addition to bacterial respiration that was continuously tracked over time. All bacterial communities showed a similar pattern in total organic carbon degradation which positively correlated with the amount of LMWS. The results suggest that the molecules with low molecular sizes are preferentially degraded by bacteria independent of their origin but might not be detectable in natural aquatic systems as they are immediately consumed. The temporal utilization of LMWS is thereby independent from the quantity and quality of the DOC pool.

The terrestrial part of this WP was carried out within the PhD thesis of Kai Nitzsche and complemented by additional assessents. In moraine landscapes, carbon (C) and nitrogen (N) dynamics can vary greatly across landscape structures and soil types but also by the water bodies interspersed. Given the strong spatial heterogeneity of moraine landscapes, the sole focus on larger (landscape) scale processes may result in the ignorance of small-scale variability in C and N dynamics. To improve predictions of the impacts of global change on landscapes and to ensure their sustainable use, it is essential to identify the driving mechanisms underlying the aquatic-terrestrial C and N dynamics. The major focus of the work carried out in this part of the project was to study stable isotope patterns to identify these regulating mechanisms across different scales (from regional landscape over kettle hole to aggregate scale) in the moraine landscape of NE Germany.
At the regional landscape scale, $\delta^{13}C$ isoscapes (*iso*topic land*scapes*) of topsoil bulk soil organic matter (SOM) and plant leaves collected from a 38.2 km^2 landscape unit revealed long-term inputs of organic matter (OM) from C_3 crops, which imprinted their water use efficiency status onto the soil, as well as short-term inputs from corn (C_4 crop). The $\delta^{15}N$ SOM isoscape identified fertilization-induced impacts of land-management on the N dynamics of agricultural fields and grasslands, while showing that the forest N cycle was rather closed (Nitzsche et al. 2016). Sediments from the small water bodies received substantial inputs from surrounding field vegetation but were also affected by seasonal drying.
A more detailed analyses of OM balance of the kettle holes on the landscape scale, surface sediments were analyzed for 51 kettle holes located in the same landscape unit but differing with respect to the surrounding land-use type and the hydroperiod. Results for $\delta^{13}C$ and $\delta^{15}N$ reflected recent OM inputs and processes and pointed at the effect of anoxic sediment conditions and fertilization in the catchment. Deeper sediments recorded the degree to which OM had been processed within the kettle hole depending on the hydroperiod and indicated the burial of OM originating from terrestrial plants (Nitzsche et al. 2017a).

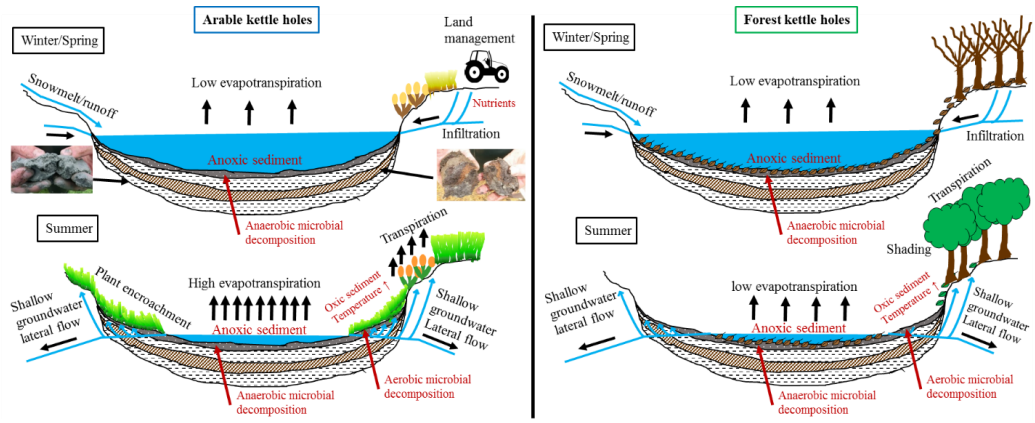


Fig. 3: Graphical abstract for land-use impacts on kettle hole sediment biogeochemistry (Nitzsche et al. 2017).

At the transect scale, erosion and plant productivity were the dominant drivers affecting mineral-associated OM fractions in topsoil sampled along transects spanning erosional to depositional areas in the catchment of one arable kettle hole. In contrast, freely available and aggre-

gated OM fractions were influenced by microbial decomposition and slurry fertilization. At the aggregate scale, the pathway and magnitude of OM-mineral associations changed along the transect while binding OM of different status of decomposition. OM in mineral-associated fractions from sediments was derived from clay- and silt-sized particles from the agricultural field together with emergent macrophyte contributions to freely available and aggregated OM fractions (Nitzsche et al. 2017b).

By means of stable isotopes techniques, different mechanisms were successfully identified at the individual scales. Consideration of the spatial heterogeneity of all scales from aggregate scale to the entire landscape is essential to understand landscape C and N dynamics. Small inland water bodies like kettle holes are key constituents with respect to C and N dynamics in moraine agricultural landscapes, because they function as important sinks for OM and alter the environmental conditions in their catchments. However, their net role as C and N sinks or sources in landscapes needs to be determined by future studies comprising longer time scales and more detailed studies on N and C fluxes.

WP2 Fluxes - Coupling C gas fluxes with underlying drivers & processes at different scales

Peter Casper (IGB), Carolina Lisboa, Angelina Jaconi (ZALF), Annette Freibauer (Thünen Institut, Braunschweig)

Work package 2 investigated long term measurements of gas exchange at aquatic and terrestrial sites. The main aim of WP2 was the estimation of fluxes of greenhouse gases (GHG), namely of methane (CH_4) and carbon dioxide (CO_2), to the atmosphere. The analyses were performed along transects in both environments selected for the project (kettle holes Kraatz and Rittgarten). CH_4 and CO_2 fluxes were measured with the static chamber technique in a recirculation mode coupled to a new generation ultraportable greenhouse gas analyzer equipped with an off-axis integrated cavity output spectroscopy (OA-ICOS, UGGA 30P, Los Gatos Inc., San Jose CA, USA). The static chambers were floating or fixed to the soil/sediment surface and shaped with two gas valves port.

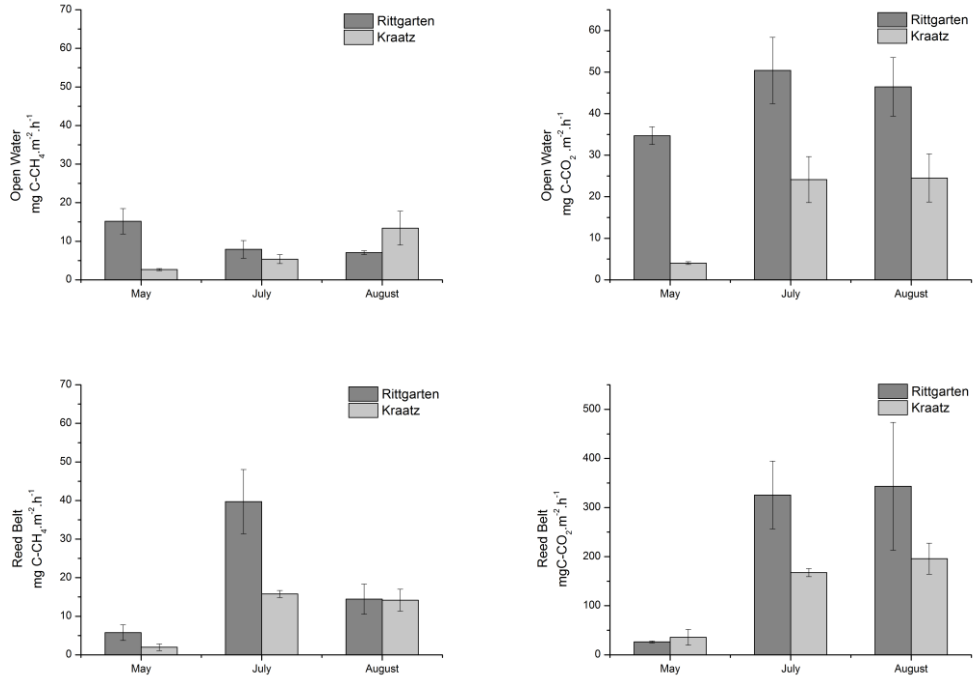


Fig. 4: Fluxes of CH_4 (left) and CO_2 (right) from open waters (top) and reed stands (bottom) in summer from Kraatz and Rittgarten kettle holes; please note the different scale of y-axis for CO_2-reed belt).

Both sites –the macrophyte belt surrounding the kettle hole and the water body - are sources for both GHGs in both kettle holes. There was a temporal development with increasing emission rates towards the summer. The different kettle holes selected for this study were only slightly different in the release of GHGs. In Rittgarten higher emission rates were found for methane and carbon dioxide. The observation that the macrophytes belt is a source for GHGs might be caused by the function of the plant tissue as a kind of chimney, transporting gases through aerenchyma from sediments directly to the atmosphere. Additionally, such plant-belts act as sink for organic material, originated from the plants themselves, but also for allochthonic material. As Rittgarten exhibit in summer short periods of anoxia, anaerobic processes in sediments produce reduced compounds, mainly CH_4, and high mineralization rates and metabolic activities lead to higher CO_2 transfers.

WP3 – Structures: Impact of landscape structure and heterogeneity on C fluxes across scales

Sabine Hilt, Garabet Kazanjian (IGB), Carsten Hoffmann, Michael Sommer, (ZALF)

The goal of WP3 at the terrestrial side was to quantify the impact of landscape structure and heterogeneity on C fluxes across scales. Due to technical reasons the originally suggested key technique, the unmanned aerial vehicle, was not operational during the LandScales project duration, unfortunately. Therefore we studied the spatio-temporal dynamics of wheat's net primary production (NPP) and C export (harvest) at representative sites in one catchment (Kraatz) over two years. C exports ranged between 100 and 500 g C m^{-2} y^{-1} depending on the annual weather conditions (wet > normal year) as well as soils (in normal year), respectively. Furthermore, we developed a new mass balance approach for soil erosion based on modern soil sensing techniques (pXRF, VIS-NIR, Mid-FTIR spectroscopy). The model results showed that approx. 90% of the soil material (and SOC) translocated over time did not reach the water body (i.e. the kettle hole). Instead the terrestrial part of the catchment served as the main storage area for lateral C fluxes. From both findings, the significance of local soil heterogeneity to achieve a comprehensive understanding of landscape scale C balances became evident.

Spatio-temporal dynamic of NPP and climatic variability are key variables for C-fluxes into the terrestrial system: The dynamic of the net primary production (NPP) was measured by Hoffmann et al. at the micro-catchment (Kraatz) during the growing periods of winter wheat in 2014 (wet year) and 2015 (dry year): (1) Leave Area Index (LAI), bi-weekly; (2) plant height (bi-weekly), and
(3) dry matter and C-contents of grains and straw (one time, shortly before the harvest).

In the wet year with sufficient water availability and waterlogged depressions, the average grain production was significant higher compared to that in the dry year (833 g m^{-2} and 452 g m^{-2}, respectively). In both years the average straw production was almost the same (828 g m^{-2} to 760 g m^{-2}, respectively). In wet years, total biomass production was not related to soils types and topography. In the dry years the average biomass production was some higher in the depression (Colluvic Regosols) compared to that at the local summits (Calcic Regosols). The

C-export by grain was between 100-500 g C m^{-2} as depended on both, meteorological conditions and topography.

A multi-sensor application (VisNIR, pXRF and Mid-FTIR) on soil cores delivers high spatial soil data densities and improves models to quantify past erosional process: Three-dimensional soil landscape models require a lot of data for calibration and validation. Fast and reliable methods to measure soil attributes in a high vertical resolution would meet this demand. An effective soil sampling and digital soil morphometric technology was developed by Hoffmann et al. based on preliminary studies of our cooperation partner (Group Kristof van Oost, Université catholique de Louvain, BE). Spectroscopy measurements by VisNIR- (visible bear infrared), pXRF- (portable X-ray fluorescence)-, and Mid-FTIR (Mid-Infrared Fourier Transform Infrared) on halved, dried and polished soil cores were combined. The method provides rapid and cost-efficient depth functions of SOC (quantity and quality), elements and diverse soil functional groups. First analyses showed that the multi-sensor application is a promising technology to develop e.g. 3D soil landscape models on SOC and erosion/deposition status of soils.

Erosion and deposition sites localized and quantified (terrestrial-aquatic): Based on the multi-sensor application the spatial distribution and amount of (past) eroded and accumulated soil material was derived. Vertical distributions of Ca and Fe (by pXRF spectroscopy) and aliphatic C-H groups (FTIR) were used to quantify soil profile shortening at erosional sites and input of upslope material at foot slopes, respectively.
It was found that past soil erosion within the Kraatz micro-catchment caused considerable redistributions of surface and sub-soil material within the terrestrial system and from the terrestrial into the aquatic system (kettle hole in the centre of the micro-catchment). Some 35 % and 44% of the area are affected by erosion and deposition, respectively, which is very typical for the regional agricultural landscape. Maximum profile shortening and accumulation thickness were found to be up to 1.5 m. The total eroded material was quantified by 9,970 m^3, the volume of colluvium (=terrestrial accumulation) by some 8,890m^3. The balance of both, some 1,080m^3 is missing in this calculation, was expected to be transported into the kettle hole.

SOC stocks were quantified by different vertical and horizontal segments: Spectroscopic VisNIR measurements were made at 28 soil cores with vertical distributions of 3 cm. By this method in total 860 spectra were collected. Lab measurements for calibration (n=85) were used to develop and train a Cubist Model to predict SOC contents for all measured spectra. The validation of predicted to observed values (n=30) resulted in a coefficient of determination (R^2) of 0.53 and a RMSE of 0.3 % (with SOC range between 0.04-1.54%).
A combination of the spatial distributions of the three relief parameters TWI (Topographical Wetness Index), TPI100 and TPI200 (Topographical Position Index) and the Electric Conductivity (ECA) correlated well with the bulk density of Ap-horizon and was combined within a linear regression model (R^2=0.57). By combining SOC concentrations with bulk density, SOC stocks for the Ap-horizon were calculated for the total micro-catchment. The range of SOC stocks in Ap-horizon (0- 20 cm) was between 1.1 kg SOC m^{-2} at summits and 4.5 kg SOC m^{-2} in the depression.

Aquatic part - deviations from original concept: The initial idea of the aquatic part of this subproject was a strong link with a ZALF postdoc aiming at the calibration of spectral information local ground truthing of primary production in sediments of selected kettle holes and lakes. Due to difficulties in the postdoc recruitment, the IGB PhD student now aimed at answering the following questions:

1. How does aquatic primary production affect nutrient and carbon cycling in small water bodies dominated by benthic primary producers?
2. How will the upcoming environmental changes (global warming, DOC increase) drive aquatic primary production?
These questions were dealt with using three approaches: 1) a one year series of field measurements of primary production in two hypertrophic kettle holes with a different dominance of primary producers, 2) two three-months laboratory studies on periphyton primary production in limnotrons with a normal temperate and a warmed (+4°C) temperature scenario with and without macrophyte presence and 3) a field study on the longer-term effects of temporal brownification on phytoplankton and periphyton primary production in a small eutrophic shallow lake.
Main achievements: The investigations by Kazanjian et al. in two typical kettle holes revealed that emergent macrophytes dominated gross primary production (GPP) accounting for about half of GPP in both studied systems, while periphyton prevailed throughout the rest of the year. During summer, phosphorus release from the sediment was higher in the duckweed-covered kettle hole, as were sediment deposition rates, which here were strongly correlated to GPP (Kazanjian et al., in revision). Aerobic sediment mineralisation was significantly lower in the duckweed-covered kettle hole due to prolonged periods of anoxia, but this might have been offset by higher (non-aerobic) methane production (Kazanjian et al., in revision; Flury et al., in revision).
The limnotron experiments revealed that warming by 4°C significantly enhanced both bottom-up and top-down control of periphyton production in temperate fishless mesocosms (Kazanjian et al., in prep. a). In contrast warming reduced phytoplankton biomass (Velthuis et al., 2017). These changes in primary production have significant consequences for methane ebullition from these systems (Aben et al., 2017).
Multi-year data of Lake Gollinsee showed a differential response of summer primary production of periphyton and phytoplankton to a temporal browning effect that started in 2011and was followed to 2014 (Kazanjian et al., in prep). Using time series of oxygen concentrations of a similar lake we could show that the commonly used diel oxygen curves approach may not be appropriate lad to an underestimation of GPP (Brothers et al., 2017).

WP 4 Modelling - Uncertainties in scaling fluxes and mechanisms to the landscape level

Gunnar Lischeid, Mohamed Omari, Gabriela Onandia, Florian Revery (ZALF)

Work package 4 of the LandScales project aimed at upscaling findings from detailed process studies at two kettle holes to the landscape level and to assess the associated uncertainties by applying a set of advanced tools of multivariate non-linear statistical analyses, like Support Vector Machines, Genetic Algorithms and Self-Organizing Maps.
However, filling the PhD position with a candidate with both sound skills with respecrt to these approaches as well as in freshwater or landscape biogeochemistry was not successful. Thus, the approach was modified. To compile and test the existing knowledge about turnover of carbon, nitrogen and phosphorus in the kettle hole, a biogeochemical model was developed and calibrated using the data set of the Rittgarten site. However, the respective PhD student, Mohamed Omari, decided after some to for another PhD project in medical science and left before the paper was finished. The paper will be finished but with delay The position was then filled by a postdoc, Gabriela Onandia, who had developed a model for biogeochemical processes in a lagoon. That model was adapted to the specific conditions of the Rittgarten site, using the LandScales data for calibration (Onadia et al, in prep.).
Due to the complexity and the large number of the biogeochemical processes in small kettle holes and their adjacent arable areas, any modeling of carbon dynamics in kettle holes should take into account interactions between multiple elements, e.g. carbon, nitrogen, phosphorus,

oxygen and other chemical elements. A significant fraction of these elements originates from agricultural areas and are transported to the kettle holes via wind or water erosion. This input is processed by phytoplankton, macrophytes, bacteria and fungi which are the key players for biomass production and decomposition. For this, a complex eutrophication model was developed for the Rittgarten kettle hole which is surrounded by arable fields located in eastern part of Germany to get an insight into the substantial short-term variations of these processes, assessing carbon budget and to best understand their effects on water quality as well. The model combines phytoplankton as a single group and describes its interaction with duckweed, nutrients, organic and inorganic matters in the overlying water. In addition, the model takes into consideration the phosphate-iron and Manganese interactions. The sensitivity analysis is conducted to determine the most sensitive parameters. This enables further exploration of the universality and robustness of the model and its parameters. Finally, we conducted the calibration procedure to match the simulated model output with the observed data by monitoring Rittgarten kettle hole for a period of one year (Omari et al. in prep.).

In addition, the issue of upscaling and representativity was addressed in cooperation with LandScales partners and by additional studies of the group of the PI of WP 4, mostly financed by ZALF internal money. The isoscape approach applied in WP 1 was used to characterize a large number of kettle holes in the region and to study effects of temporary desiccation of the kettle holes (Nitzsche et al. 2017a,b). LandScales findings as well as additional data from the group of the PI indicated that these phases might play a crucial role for the biogeochemistry of kettle holes. Thus, an additional PhD project was initiated that focused on biogechemical and microbial processes in kettle hole sediments during these phases (Reverey et al. 2016, Reverey et al, in prep.). The project is still ongoing. In addition, analyses of sediment traps and of sediment cores from both LandScales sites were used to study both land use effects of the last decades as well as the respective prevailing processes (Kleeberg et al. 2016a, b).
The study by Reverey et al. investigated the hydrological regimes and its impact on kettle holes. Drying of sediments boosts carbon mineralization and thus drives CO_2-emissions to the atmosphere, whereas rewetting leads to a sharp decrease. Thus, the mineralization efficiency is highest in dry sediment. On the other hand, kettle hole sediments partly become a methane sink during dry phases, indicating increased methanotrophic activity; after rewetting, methane production increases again.
Dry-wet cycles create a sediment memory effect regarding carbon and nitrogen cycling. In zones which are frequently exposed to dry-wet cycling, OM is more humic and there is a lower overall biological activity than in zones less exposed. However, carbon is mineralized more efficiently in zones frequently exposed, indicating impacts on the microbial community, possibly shifts of the community towards that of soils where OM is more complex. In zones which are usually inundated, there are indications of microbial die-off and cell lysis, which would also explain lower microbial activity. Nitrogen loss is potentially higher in zones frequently exposed to dry-wet cycling, as the ratio between denitrifiers and microbes capable of DNRA (which can retain N in the system) is higher in these zones.

Representatively of findings at the two selected sites could be checked based on data from an extensive kettle hole, groundwater and stream water monitoring program (Lischeid et al. 2016, Lischeid et al. 2017a). It could be shown that short-term variability of kettle hole water differed substantially from that in small streams, pointing to the prominent role of nutrient and carbon turnover and transient anoxic conditions in kettle holes. In addition, there was clear evidence for a major role of shallow groundwater with respect to water level dynamics and water quality in the kettle holes (Lischeid et al. 2017b). A detailed hydrological model revealed a complex pattern of exchange between kettle hole and shallow groundwater (Gliege et al. in prep.). However, based on isotope data by Nitzsche et al. (2017a) water residence

time within the kettle hole basins could be assessed. It was in the range of a few years for most kettle holes, which is some orders of magnitude larger compared to the kinetics of most biogeochemical processes within the kettle holes. Thus, groundwater provides a steady supply of nutrients and inorganic carbon to the kettle holes and determines water stage dynamics. However, turnover of nutrients and carbon within the kettle holes primarily depends on internal processes.

The model developed by Onandia et al. is partially based on a biogeochemical model established for hypertrophic waterbodies (Onandia et al., 2015) and considers the interplay between the following state variables: nitrate, ammonium, organic nitrogen, phosphate, organic phosphorus, dissolved organic carbon, particulate organic carbon, dissolved inorganic carbon, dissolved oxygen, phytoplankton, free-floating macrophytes and dissolved oxygen. The model was manually calibrated to match the observed state variables dynamics from July 2013 to July 2014 in the Rittgarten kettle hole. Afterwards, the model performance was assessed and a sensitivity analysis was completed. Finally, we quantified the simulated nutrient mass fluxes derived from the ecological processes considered by the model.
The developed model reasonably reproduces the observed seasonal dynamics of phytoplankton, free-floating macrophytes, and their annual succession in the pond. Likewise, the model is able to reproduce the dynamics of dissolved oxygen, as well as the phosphorus and carbon cycle state variables in Rittgarten. The sensitivity analysis indicated that the model outputs were most sensitive to parameters modulating phytoplankton growth and losses as well as the duckweed mortality rate and therefore, the improvement of the model predictions relies upon the experimental determination of these parameters in the future. The cumulative N and P annual fluxes associated to the ecological processes indicate that phytoplankton consumes most of the nutrients removed by primary producers. The results additionally show that the nutrients made available via recycling cannot meet the free floating macrophytes´ and phytoplankton phosphorus and nitrogen requirements. This suggests that external and internal (via sediment) loadings constitute a fundamental nutrient source for the primary producers in the kettle hole and highlight the potential impact of catchment land-use on the ecological functioning of the pond. In addition, the results suggest that the pelagic compartment of the kettle hole acts as a net C source to the atmosphere. Finally, we identified the consideration of allochthonous inputs, more detailed sediment-water interactions and the addition of trophic levels as desirable model augmentations.

WP additional: Element-specific fluxes, metabolism and vegetation of kettle holes

Andreas Kleeberg, Thomas Kalettka (ZALF)

Sediment cores from kettle holes in NE Germany reveal recent impacts of agriculture: Glacial kettle holes in young moraine regions receive abundant terrigenous material from their closed catchments. Core chronology and sediment accumulation were determined for two semi-permanent kettle holes, designated Rittgarten (RG) and Kraatz (KR), on arable land close to the villages of Rittgarten and Kraatz, respectively, in Uckermark, NE Germany. Core dating (^{210}Pb, ^{137}Cs) by Kleeberg et al. (2016b) revealed variable sediment accretion rates through time (RG: 0.4 - 23.1 mm a^{-1}; KR: 0.2 - 35.5 mm a^{-1}), with periods of high accumulation corresponding to periods of intensive agricultural activity and consequent erosional inputs from catchments. Sediment composition (C, N, P, S, K, Ca, Fe, Mn, Zn, Cu, Mo, Pb, Cd, Zr) was used to determine sediment source and input processes. At RG, annual P input increased from 0.65 kg ha^{-1} in the early 19th century to 1.67 kg ha^{-1} by 2013. At KR, P input increased from 0.6 kg ha^{-1} to 4.1 kg ha^{-1} over the last century. There was a concurrent increase in Fe input in both water bodies. Thus, Fe:P ratios showed no temporal trend and did not differ between RG (18.5) and KR (18.4), indicating similar P mobility. At RG, the S:Fe ratio increased from 0.4

to 2.3, indicating more iron sulphides and thus higher P availability, coinciding with high coverage of duckweed (*Spirodela polyrhiza* (L.)) and soft hornwort (*Ceratophyllum submersum* L.). At KR, however, this ratio remained low and relatively unchanged (0.3 ± 0.4), indicating more efficient Fe-P binding and lower hydrophyte productivity. Trends in sediment composition indicate a shift towards eutrophication in both kettle holes, but with differences in timing and magnitude. Other morphologically similar kettle holes in NE Germany that are prone to erosion could have been similarly impacted, but may differ in the extent of sediment infilling and degradation of their ecological functions. It was also observed that pulsed losses from the terrestrial domain contributed to erosion.

Another project by Kleeberg et al. (2017a) investigated the element-specific downward fluxes and the impact on metabolism and vegetation of kettle holes: Given that water-filled kettle holes are mostly undergo a wet-dry cycle, and are directly fuelled by terrigenous material, it was hypothesized that the downward flux of matter, including P and its binding partners, varies between and within kettle holes, and is closely coupled to the prevalent water regime. Sedimentation was studied in two kettle holes close to Rittgarten (RG) and Kraatz (KR), Uckermark, NE Germany. Pairs of cylindrical traps at three sites in each kettle hole were sampled biweekly (June 2013 - July 2014). Mean fluxes decreased with decreasing water level. KR was Fe-dominated binding P, and had submersed macrophytes. RG was Ca-dominated and had low Fe concentrations suggesting that both apatite and oxidized Fe compounds equilibrating P release, with finally a surplus in P. Thus, RG was covered by duck weed. The higher C-flux fuelled the sulphate reduction at higher rates than in KR, as also favoured by oxygen deficits due to duck weed coverage. Thus, internal eutrophication, i.e., where sulphate reduction and Fe sulphide formation lead to a lower Fe availability for P binding, is an issue for kettle holes increasingly degrading their ecosystem services.

(4) Economic availability

No direct economic results were produced.

(5) Cooperation partner

Advisory board:

- Prof. Dr. George Arhonditsis. Chair of the Department of Physical and Environmental Sciences, University of Toronto, Scarborough, Canada.
- Professor Dr. Mike Billett, Biological & Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling, FK9 4LA, Scotland, UK,
- Dr. Bernard Longdoz, Chargé de Recherche INRA, Centre INRA Nancy, UMR Ecologie et Ecophysiologie Forestières, Rue d'Amance, 54280 Champenoux

Other cooperation partner:

- Emilien Aldana Jague, Group Kristof van Oost, Université catholique de Louvain, BE
- Dr. Till Francke (University Potsdam) - University supervisor of Marielle Neyen (B.Sc.)
- Sabine Stahl (University Bremen, Geomorphology and Polar Research) – μXRF measurements
- Uwe-Karsten Schkade (Federal Office for Radiation Protection) – core dating
- Prof. Dr. Ligy Philipp, Indian Institute of Technology Madras
- Prof. Dr. Peter Fiener, University of Augsburg, Department of Geography
- Dr. Robert van Geldern, Friedrich-Alexander University Erlangen-Nuremberg (FAU), GeoZentrum Nordbayern
- Dr. Rota Wagai, NARO Institute for Agro-Environmental Sciences, 3-1-3 Kan-nondai, Tsukuba, Ibaraki, 305-8604, Japan

- Dr. Michael Kaiser, University of Kassel, Department of Environmental Chemistry, Nordbahnhofstr. 1a, 37213 Kassel

(6) Student qualifications

- Kazanjian, G. Primary production in small water bodies. PhD, Humboldt-University Berlin, since 3/2013.
- Nitzsche, K. Applying isotope geochemistry to identify mechanisms regulating the aquatic-terrestrial carbon and nitrogen dynamics across scales in a moraine landscape. PhD, Humboldt-University Berlin, 1/2013-12/2016 (5/2017 Thesis defended, fund-raised successfully a Humboldt fellow ship for two years in Japan).
- Reverey F. Carbon and Nutrient Cycling and hydrological regimes in Kettle Hole Sediments. PhD, University of Potsdam, since 4/2014.

(7) Young researchers involved (employed PostDocs)

- Carsten Hoffmann, ZALF Müncheberg
- Carolina Lisboa, ZALF Müncheberg
- Gabriela Onandia, ZALF Müncheberg
- Sabine Flury, IGB Berlin
- Katrin Attermeyer, IGB Berlin

(8) Master and Bachelor students involved

- Eric Hübner (Master Thesis 2016, IGB): Influencing factors on carbon turn-over in kettle holes; Supervisor: Katrin Premke
- Jan Oestmann (Master Thesis 2015, IGB): Microbial utilization of two different complex carbon sources; Supervisor: Katrin Premke, Katrin Attermeyer
- Jaël Brüning-Langhammer(Master Thesis 2014, IGB): The role of ebollution of pore water exchange at sediment water interface; Supervisor: Katrin Premke; Sabine Flury
- M. Neyen (B.Sc. Thesis 2014, ZALF): Depositional characteristics of glacial kettle holes at Kraatz and Rittgarten, NE Brandenburg, Germany. Supervisor: Gunnar Lischeid, Andreas Kleeberg, Thomas Kalettka
- R. Heitmann (B.Sc. Thesis 2017, ZALF): Assessing the release of DOC, P, and Fe from flooded peat soils in oxic and anoxic conditions. Supervisor: Gunnar Lischeid, Thomas Kalettka

(9) Other tasks

Summer schools

- Gabriela Onandia participated at "The next generation of biodiversity research: theory, traits and methods", Biodiversity workshop, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), 7th – 9th October, 2015.
- Gabriela Onandia participated at the "25th Shortcourse on MATLAB Recipes for Earth Sciences", 8th – 12th February, 2016, University of Potsdam, Potsdam.
- Gabriela Onandia participated at the "Management Skills for Research and University", 26th – 27th April, 19th – 21th May, 15th – 16th June, 2016, University of Potsdam, Potsdam
- Carolina Lisboa participated at the 5th Summer School in Environmental Systems Analysis, Swiss Federal Institute of Aquatic Science and Technology, Zurich, Switzerland02-09/06/2013
- Kai Nitzsche participated at the 'Isotopes in Spatial Ecology and Biogeochemistry' (SPATIAL Short Course), University of Utah, 14.-26.6.2015 ; getting the Participant

Award for attending at SPATIAL summer school, University of Utah, through the National Science Foundation (NSF)

Teaching by students

- Katrin Attermeyer developed and teached the course "Adobe Illustrator and graphic illustrations of figures for scientific papers" within the doctoral program of IGB

Additional funding's

- Premke, Attermeyer, funding via the DAAD for a month the investigations in Indian at the Institute of Technology, Madras: Field trip to Chennai, India to study carbon dynamics in tropical freshwater lakes
- Premke, Attermeyer, Flury funding via the DAAD for a month the investigations in Indian at the Institute of Technology, Madras: Field trip to Chennai, India to study C turnover in and greenhouse gas emissions from a tropical freshwater lake
- Kai Nitzsche: Short-term scholarship (Japan) for PhD students through the German Academic Exchange Service (DAAD) 1.9.-31.12.2015
- Kai Nitzsche: Travel grant for participation at the AGU Fall Meeting 2013, San Francisco, through the German Academic Exchange Service (DAAD) 9.-13.12.2013

(10) Publications

Published

1. Aben R., Barros N., van Donk E., Frenken T., Hilt S., Kazanjian G., Lamers L., Peeters E., Roelofs J., de Senerpont Domis L.N., Stephan S., Velthuis M., van de Waal D.B. & Kosten S. Cross continental increase in methane ebullition under climate change. *Nature Communications* 8, 1682.
2. Attermeyer, K., H.-P. Grossart, S. Flury, K. Premke (2017) Bacterial processes and biogeochemical changes in the water body of kettle holes - mainly driven by autochthonous organic matter? Aquatic Sciences 79:675-687.
3. Attermeyer, K., S. Flury, R. Jayakumar, P. Fiener, K. Steger, V. Arya, F. Wilken, R. van Geldern, K. Premke (2015) Invasive floating macrophytes reduce greenhouse gas emissions from a small tropical lake. Scientific Reports 6: 20424.
4. Flury S, R.N. Glud, K. Premke, D.F. McGinnis. 2015. The effect of sediment gas voids and ebullition on benthic solute exchange. *Environmental Science and Technology 4*9:10413-20. DOI: 10.1021/acs.est.5b01967.
5. Kalinkat, G., Cabral, J. S., Darwall, W., Ficetola, G. F., Fisher, J. L., Giling, D. P., Gosselin, M.-P., Grossart, H.-P., Jähnig, S. C., Jeschke, J. M., Knopf, K., Larsen, S., Onandia, G., Pätzig, M., Saul, W.-C., Singer, G., Sperfeld, E., Jarić, I. (2017): Flagship umbrella species needed for the conservation of overlooked aquatic biodiversity. Conservation Biology31(2):481-485
6. Kleeberg, A., M. Neyen, U.-K. Schkade, T. Kalettka & G. Lischeid (2016b): Sediment cores from kettle holes in NE Germany reveal recent impacts of agriculture. Environmental Science and Pollution Research 23(8): 7409-7424. DOI 10.1007/s11356-015-5989-y
7. Kleeberg, A., Neyen, M., Kalettka, T. (2016a): Element-specific downward fluxes impact the metabolism and vegetation of kettle holes. Hydrobiologia 766, 1, 261-274
8. Lischeid, G., Kalettka, T., Merz, C., Steidl, J. (2016): Monitoring the phase space of ecosystems: concept and examples from the Quillow catchment, Uckermark. Ecological Indicators 65, 55-65
9. Lischeid, G., Kalettka, T., Holländer, M., Steidl, J., Merz, C., Dannowski, R., Hohenbrink, T., Lehr, C., Onandia, G., Reverey, F., Pätzig, M. (2017a): Natural ponds in an

agricultural landscape: External drivers, internal processes, and the role of the terrestrial-aquatic interface. Limnologica online
10. Lischeid, G., Balla, D., Dannowski, R., Dietrich, O., Kalettka, T., Merz, C., Schindler, U., Steidl, J. (2017b): Forensic hydrology: What function tells about structure in complex settings. Environmental Earth Sciences DOI: 10.1007/s12665-016-6351-5
11. Lorke A., P. Bodmer, C. Noss, Z. Alshboul, M. Koschorreck, C. Somlai, D. Bastviken, S. Flury, D. F. McGinnis, A. Maeck, D. Müller, K. Premke. 2015. Technical Note: Drifting vs. Anchored flux chambers for measuring greenhouse gas emissions from running waters. *Biogeosciences* 12, 14619-14645.
12. McGinnis, D. F., N. Bisley, M. Schmidt, P. Fietzek, P. Bodmer, K. Premke, A. Lorke, S. Flury. 2016. Deconstructing methane emissions from a small Northern European river: hydrodynamics and temperature as key drivers. *Environmental Science and Technology* 50:11680-87 DOI: 10.1021/acs.est.6b03268.
13. McGinnis D. F., G. Kirillin, K. W. Tang, S. Flury, P. Bodmer, C. Engelhardt, P. Casper, and H.-P. Grossart. 2015. Enhancing surface methane fluxes from an oligotrophic lake: Exploring the microbubble hypothesis. *Environmental Science and Technology,* 49(2).
14. Nitzsche K.N., Verch G., Premke K., Gessler A. and Kayler Z.E. *(2016)* Visualizing land-use and management complexity within biogeochemical cycles of an agricultural landscape. *Ecosphere*, 7(5):e01282. 10.1002/ecs2.1282.
15. Nitzsche, K., Kalettka, T., Premke, K., Lischeid, G., Geßler, A., Kayler, Z. (2017a): Land-use and hydroperiod affect kettle hole sediment carbon and nitrogen biogeochemistry. Science of the Total Environment 574, 46-56
16. Nitzsche K.N., Kaiser M., Premke K., Gessler A., Ellerbrock R., Hoffmann C., Kleeberg A. and Kayler Z.E. (2017b) Organic matter distribution and retention along transects from hilltops to kettle hole within an agricultural landscape. *Biogeochemistry* 136: 47-70
17. Onandia, G., Dias, J. D., Miracle, M. R. (2015): Zooplankton grazing on natural algae and bacteria under hypertrophic conditions. Limnetica 34, 2, 541-560
18. Premke, K., K. Attermeyer, J. Augustin, A. Cabezas, P. Casper, et al. (2015) The importance of landscape complexity for carbon fluxes on the landscape level: Small scale heterogeneity matters. WIREs Water 3: 601-617.
19. Reverey, F., Grossart, H.-P., Premke, K., Lischeid, G. (2016): Carbon and nutrient cycling in kettle hole sediments depending on hydrological dynamics: a review. Hydrobiologia 775, 1, 1-20
20. Kazanjian G., Flury S., Attermeyer K., Kalettka T., Kleeberg A., Premke K., Köhler J. & Hilt S. (2017) Primary production in nutrient-rich kettle holes with differing plant communities and consequences for nutrient and carbon cycling. *Hydrobiologia*. DOI10.1007/s10750-017-3337-6
21. Velthuis M., de Senerpont Domis L.N., Frenken T., Stephan S., Kazanjian G., Aben R., Hilt S., Kosten S., van Donk E. & Van de Waal D.B. (2017) Warming advances top-down control and reduces producer biomass in a freshwater plankton community. Ecosphere 8: e01651
22. Brothers S., Kazanjian G., Köhler J., Scharfenberger U. & Hilt S. (2017) Convective mixing and high littoral production established systematic errors in the diel oxygen curves of a shallow, eutrophic lake. Limnology & Oceanography Methods 15:429-435.
23. Reverey, F., Ganzert L., Lischeid, G., Ulrich A., Premke, K., Grossart, H.-P. (2017) Microbial and Biogeochemical Processes Display Memory Effects during Dry-Wet Cycles of Kettle Hole Sediments. Science of the Total Environment

In revision

- Flury S., Attermeyer K., Kazanjian G., Zlatanovic S., Grossart H.P, Hilt S., Casper P. & Premke K (*in revision)*. Benthic microbial mineralization and organic carbon uptake in kettle holes: lignin-poor organic carbon as a major driver. *Limnology & Oceanography*.

(11) Conference presentations (oral only)

- Casper, P.; Martinez-Cruz, K.; Fuchs, A.; Cardoso Lisboa, C.; Reverey, F.; Rodriguez, M.; Sepulveda-Jauregui, A.; Ullrich, N. (2015): METHANE DYNAMICS IN TEMPERATE AQUATIC SYSTEMS: PRODUCTION; OXIDATION; EMISSION; ASLO Granada, Spain. *Oral presentation*
- Sabine Flury, Katrin Attermeyer, Sanja Zlatanovic, Katrin Premke. Do benthic microbes care about their food source? Sediment mineralization in kettle holes in northeastern Germany. DGL 2015. (oral) (21.-25.09.2015)Essen. Germany.
- Attermeyer K., S. Flury, R. Jayakumar, K. Steger, P. Fiener, V. Arya, R. van Geldern, K. Premke: Floating macrophytes reduce greenhouse gas emissions in a tropical lake (oral) (05.-10.07.2015) SEFS 2015 in Geneva, Switzerland
- Attermeyer, K., S. Flury, R. Jayakumar, V. Arya, K. Steger, P. Fiener, K. Premke: Bioinvasion von Wasserhyazinthen verändern die Kohlenstoffumsetzung und Emissionen von Treibhausgasen in einem subtropischen See in Südost-Indien, (oral) (29.09.-02.10.2014) DGL 2014 in Magdeburg, Germany
- Attermeyer, K., S. Flury, G. Kazanjian, A. Gessler, K. Premke: The role of oxygen, temperature, and sediment organic carbon on sediment mineralization rates in kettle holes in Northeast Germany (oral) (18.-23.05.2014) ASLO 2014 in Portland, Oregon, USA
- Hoffmann, C. Sommer, M., Höhn, A., Onasch, I. 2015: Multi-sensor approach for modelling element and SOC-depth functions. Oral Presentation. Global Workshop Digital Soil Morphometrics, Madison, WI.
- Hoffmann, C., Leue, M., Sommer, M. 2015: Multisensoreinsatz an Bohrkernen als Grundlage für die 3D-Modellierung von Stoffmustern in Bodenlandschaften. (Poster) DBG-Jahrestagung 2015, München.
- Sabine Flury, Jael Brüning, Katrin Premke, Daniel Frank McGinnis. A new look at an old problem – enhanced internal nutrient loading through ebullition processes. JASM2014. Portland Oregon. USA.
- Velthuis, M., Aben, R., Kazanjian, G., Kosten, S., Hilt, S., Peeters, E., Van Donk, E. & Bakker, L. (2016) Warming advances phenology and increases biomass of a freshwater macrophyte. SIL meeting, Torino (Italy).
- Kazanjian, G., Flury, S., Attermeyer, K., Premke, K., Köhler, J., Hilt, S. (2015). Small water bodies pose unique primary production dynamics: consequences of alternative regimes in kettle holes. Conference of the Association of the Sciences of Limnology and Oceanography (ASLO), Granada (Spain).
- Kazanjian, G., Flury, S., Attermeyer, K., Premke, K., Köhler, J., Hilt, S. (2014). Consequences of contrasting macrophyte dominance in hypertrophic kettle holes of temperate moraine landscapes. 8th Shallow Lakes Conference, Antalya (Turkey).
- Kazanjian, G., Flury, S., Attermeyer, K., Premke, K., Köhler, J., Hilt, S. (2013). Consequences of contrasting macrophyte dominance in hypertrophic kettle holes of temperate moraine landscapes. Annual meeting of the German Limnological Society (DGL), Potsdam.
- Onandia G., F. Reverey, T. Kalettka, A. Kleeberg, G. Lischeid & G. Arhonditsis: Modeling nutrient, phytoplankton and floating macrophytes dynamics in kettle holes

in Northeast Germany. 18th Conference of the Iberian Association of Limnology, July 4 - 8 2016. Tortosa, Catalonia, Spain. – oral contribution

- Onandia G., Miracle M.R., Gudimov A., Arhonditsis G. "*A biogeochemical modeling approach to address the eutrophication problems in the shallow hypertrophic lagoon Albufera de Valencia*". 18th Conference of the Iberian Association of Limnology, 4th – 8th July, 2016, Tortosa (Catalonia, Spain. Oral communication
- Nitzsche K.N., Premke K., Gessler A., Verch G. and Kayler Z., Visualizing land-use and management complexity within biogeochemical cycles of an agricultural landscape. *Japanese Society of Biogeochemistry Fall Meeting*, Towada City, Japan, November 2015, oral presentation.
- Kalettka, T., M. Neyen, U.-K. Schkade & A. Kleeberg: Sediment accumulation in glacially created kettle holes on arable land, Uckermark, NE Germany. 8th Shallow Lakes Conference, 12 - 17 October 2014, Antalya, Turkey – oral contribution
- Lischeid, G., K. Attermeyer, P. Bodmer, P. Casper, S. Flury, A. Freibauer, A. Gessler, H.-P. Grossart, S. Hilt, C. Hoffmann, A. Jaconi, T. Kalettka, Z. Kayler, G. Kazanjian, A. Kleeberg, C. Lisboa, D. McGinnis, K. Nitzsche, M. Omari, M. Pätzig, K. Pirhofer-Walzl, K. Premke, F. Reverey, M. Sommer: Kettle holes: Hot-spots of biodiversity, carbon dynamics and greenhouse gas emissions in an agricultural landscape. TERENO International Conference 2014, 29 September - 2 October 2014. Rheinische Friedrich-Wilhelms-Universität Bonn, Germany. - oral contribution
- Neyen, M., U.-K. Schkade, T. Kalettka & A. Kleeberg: Besonderheiten der Sedimentation und Stoffakkumulation in glazial geprägten Ackerhohlformen (Söllen) der Uckermark (Nordost-Brandenburg). Jahrestagung der Deutschen Gesellschaft für Limnologie, 29.09. - 02.10.2014, Magdeburg. - oral contributio
- Premke, K., K. Attermeyer, P. Bodmer, P. Casper, S. Flury, A. Freibauer, H.-P. Grossart, S. Hilt, C. Hoffmann, A. Jaconi, T. Kalettka, A. Kleeberg, Z. Kayler, G. Kazanjian, D. McGuinnis, C. Lisboa, K. Nitzsche, M. Omari, M. Sommer & A. Gessler: Connecting processes and structures driving carbon dynamics over landscape scales. Jahrestagung der Deutschen Gesellschaft für Limnologie, 29.09. - 02.10.2014, Magdeburg. – oral contribution
- Reverey F, Premke K, Grossart HP, Lischeid G. Sediment memory effects on carbon and nutrient turnover in hydrologically highly dynamic kettle holes? SIL-Conference August 2016 Torino; Oral
- Kayler Z., Nitzsche K.N., Gessler A., Kaiser M.L., Hoffmann C., Premke K. and Ellerbrock R. From hilltop to kettle hole: What trends across the aquatic-terrestrial transition zone are revealed by organic matter stable isotope ($\delta^{13}C$ and $\delta^{15}N$) composition? *49th American Geophysical Union's (AGU) Fall Meeting*, San Francisco, December 2016, oral presentation.

(12) Technicians/ Interns/student helpers involved

ZALF:
Kristina Holz – laboratory analysis
Sabine Fritsche, Ralph Tauschke - kettle hole morphometry
Bernd Schwien – sediment traps
Dorith Henning, Roswitha Schulz and Joachim Bartelt – support in sampling
Rita Schwarz, Melitta Engel – laboratory analysis
Norbert Wypler (BLF, ZALF): Field support, soil core taking and preparation.
Ingrid Onasch (BLF, ZALF): Spectroscopic measurements on soil cores, LAI and moisture measurements.

Lidia Völker (BLF, ZALF): GIS support. Preparation of DEM.
Kennedy Kwaku Kasta (IASTE intern) 1.6.-31.7.2014
Thomas Wagner (HIWI) 1.7.-31.12.2013
Ruben Yague (Technician)
Anna Buchberger (Praktikantin 28.7.-19.9.2014)

IGB:
Interns involved in field and lab support: Markus Lammel (Germany), Janneke Hippen (Germany), Sanja Zlatanovic (Serbia), Spela Kosir (Slovenia), Marjolyne Morales Fontalvo (Columbia), Amanda Cheng (Australia)
Technicans involved in lab support (chemical analysis) : Antje Lüder, Thomas Rossoll, Claudia Theel, Elke Zwirnmann, Hans-Jürgen Exner

Additional scientific support/ scinstists involved

- Prof. Wilfried Hierold (BLF, ZALF): Support in field soil classification.
- Dr. Sylvia Koszinski (BLF, ZALF): Geoelectric field measurements (EM38).
- Dr. Gernot Verch (DZA, ZALF): Contact and agreements with local farmer.

The landscales team during the yearly 2-days workshop