Long-term fire-vegetation change: data-based challenges

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Long-term fire-vegetation change: data-based challenges

Fire regimes are changing with climate change. Fire weather extremes promote an areal, temporal and severity increase of fires in many regions of the world including landscapes that naturally would be too wet or cold to burn. The long-term impacts of fire regime intensification (i.e. larger, more frequent, more severe fire in longer fire seasons) are poorly understood, especially long-term fire impacts on vegetation composition and vice versa.
Proxy-based fire reconstructions over decades to millennia and in the Quaternary can help to understand the role of fire in shaping landscapes under different climate and human land use intensities. However, fire impacts can only be understood when proxy-based fire reconstructions are analyzed in combination with vegetation reconstructions.
Multiple paleofire proxies (charcoal and molecular biomass burning residues) have been analyzed in sedimentary archives across the world. More than 1200 paleofire records are currently hosted by the Global Paleofire Database (GPD) of the International Paleofire Network (IPN) and have frequently been used for global to regional-scale data syntheses. Paleofire syntheses thereby provide powerful ways to disentangle different drivers of fire across spatial and temporal scales. Yet, the detailed relationship between fire regime, climate and vegetation change remains restricted to single site studies, such as at Lake El'gygytgyn, northeastern Siberia. To enable larger scale understanding of fire-climate-vegetation relationships, several data-based challenges need to be solved that range from compiling multi-proxy records to harmonization of records with different measurements and complying to the FAIR principles.
This workshop aims to discuss the current state in understanding large-scale fire-vegetation interactions with a focus on high latitudes. We also like to address and discuss solutions for challenges of harmonizing data formats and how to best serve the community with moving the Global Paleofire Database under the umbrella of the Neotoma data repository.

We welcome researchers, especially early career (ECRs), interested in past fire and its impact/interaction on/with vegetation to discuss their proxy data-based challenges in an open and friendly workshop in Göttingen, Central Germany – in person or online.

Organized by

Prof. Dr. Elisabeth Dietze, Landscape Geoscience, Institute of Geography, University of Göttingen, Germany

Dr. Lyudmila Shumilovskikh, Palynology and Climate Dynamics, Albrecht-von-Haller-Institute for Plant Sciences, University of Göttingen, Germany

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Contents

Keynote: The Neotoma Paleoecology Database – a brief history and outlook

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Created towards the end of the 1980s, pollen databases were the first data repositories that were publically available and served as a place for long term storage and as a research tool. From the beginning the European Pollen Database was an international effort including a larger group of people with some steering and guidance from North American palynologists. Eric Grimm was one of the architects of the structure of pollen databases that were created for North America and Europe with other continents and regions joining in later. The increasing number of regional databases lead to the development of a global pollen database, but the evolution did not stop there. Computers and the internet had developed rapidly providing new opportunities for the creation of tools and services to better display, search and analysis the data. The emergence of other palaeoecological databases sparked the idea to create a platform that could house different data types enabling multi-proxy data analysis and saving time and efforts in building tools for individual databases. This idea lead to the development of the Neotoma Paleoecology Database to supports research about ecological processes operating at time scales of 1 to 106 years, covering focused on the Quaternary to Miocene section of the geologic record. Neotoma's name refers to the behaviour of packrats (genus Neotoma), which gather diverse biological materials into their nests, to be preserved for future generations. I will illustrate this history and provide an overview of what Neotoma has become, what is currently possible and which developments are envisioned.

Keynote: Unraveling the power of using combined databases: some past, present and future examples

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The use of databases to answer complex environmental questions has enabled a quantitative and qualitative leap on our knowledge on global change. One of the terrestrial processes that best articulates the impacts of global change is fire. It is a phenomenon that depends on climatic conditions and fuel availability so burning captures processes such as global warming or rural abandonment. The study of fire over long time scales has proven to be a useful tool for defining conservation strategies today, which implies combining the knowledge we have on fire, but also the knowledge available on climate and vegetation. In this sense, the use of databases that allow the combination of all of them is essential. In this talk I will give some examples, from past, present and future studies that demonstrate the power of the combined use of palaeoscientific databases from different proxies to access global knowledge that is translational to conservation policies.

Keynote: Assessing vegetation and paleofire dynamics in SE Europe based on direct comparisons of charcoal and organic biomarker data with pollen records

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Near-future climate scenarios predict pervasive shifts in forest dynamics as a result of anthropogenic climate change. At the same time, acceleration of episodic ecosystem disturbances due to increasing fire intensity will likely lead to unprecedented terrestrial ecosystem disruptions. Considering these developments, a better understanding of the impact of fire intensity on past natural forest biomes can provide valuable insight into the vegetation response to future climate change. Whereas charcoal and organic biomarker analyses of lake and marine sediments have provided insights into past fire events, the spatial extent, intensity and triggers of paleofires have remained poorly constrained. To this end, I have paired pollen data with charcoal and organic biomarker data from diverse terrestrial settings from SE Europe, specifically from: (i) the Tenaghi Philippon peatland (northeastern Greece) and (ii) Lake Ohrid (North Macedonia/Albania), both spanning Marine Isotope Stages 11–12 (c. 350–490 ka), and (iii) Etoliko Lagoon (western Greece) spanning the past 250 years. The results provide a stimulus for critically evaluating the advantages and limitations of deciphering paleofire regimes using charcoal and organic biomarker data.

Keynote: Charcoal or no Charcoal? – An initial study of potential critical sources of error in the analysis of microcharcoal in Greenlandic palynological samples

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It is common practice to count charcoal particles alongside pollen and non-pollen palynomorphs in palynological samples. The classification of material as charcoal is dependent upon a number of morphological criteria which, in certain geological zones like granitic and metamorphic areas, could be misclassified. In a preliminary study we tested the effects of different preparation techniques on the count result of charcoal from the same samples of Greenlandic lake sediments. We demonstrate that the use of hydrofluoric acid has a major impact on the number of recorded charcoal particles. However, the results demonstrate that a potential error of >30% remains in the calculation of charcoal even when prepared with HF. We show that detrital biotite is responsible for a large fraction of particles that were misclassified as charcoal and suggest a way to minimize inaccuracy. The overall results could have a significant impact on the interpretation of past fire events or human activity as wrongly identified charcoal particles actually relate to other natural processes than burning.

Keynote: Non-pollen palynomorphs as a tool to study local boreal forest fire and disturbance dynamics

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Even though the boreal forests represent a significant biome within the Northern Hemisphere, there have not been studies of non-pollen palynomorphs (sub-fossil fungal spores and microscopic objects identified from pollen samples) devoted to untangling potentially missing information about the boreal forest dynamics. Therefore, it is crucial to test the potential of non-pollen palynomorphs in unraveling local stand-scale boreal forest history. Small forest hollows due to their size and location within the forest stands are suitable to see the local-scale vegetation variability. Three small boreal forest hollows and their surroundings in Northern Europe were analyzed using non-pollen palynomorphs complementary with pollen, plant macroremains, macrocharcoal, and dendrochronological research methods. Permutation tests were used to reveal to what degree fire, animals, and fungi influence the main tree species of boreal forests over the last few thousand years. Results reveal evidence for spruce pollen decline at times when the fungal ascospores of Lasiosphaeria cf. caudata were abundant supporting saprotrophic relationship on spruce. Findings of fungal Neurospora ascospores were used to improve the fire reconstructions. There is also a tentative indication for large herbivore interaction within the boreal tree species at a stand scale. Although further research must be carried out, at this point non-pollen palynomorphs underline their broad applicability in current and future forest ecosystem studies either the scope is solely fire or the interaction of different influencing agents.

Keynote: On FAIR Data and Samples

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In the last times, it became increasingly important to make data and also samples FAIR (Findable, Accessible, Interoperable and Reusable). Many Research Support Programs expect or encourage funded projects to make their results and data openly accessible. While open publications and data are commonly known, a more recent aspect are open samples. Physical samples or specimen are often at the beginning of the "research chain" as they are the source of much of the data described in scientific literature. The IGSN (International Generic Sample Number) is a globally unique and persistent identifier (PID) for samples and collections with a search function in the internet. IGSNs allow data and publications to be linked directly to the samples from which they are derived, closing the last gap in the complete provenance of research results. Furthermore, both, samples and data, need sufficient and, at best, standardised metadata so that users can easily find and use the data.
In this talk, I will give some insights into open data – what are open data, how can I and why should I make my data open? Furthermore. I will present the FAIR WISH project (FAIR Workflows to establish IGSN for Samples in the Helmholtz Association), which aims to create user-friendly workflows to register various kinds of samples with an IGSN in the Earth and Environmental Sciences. In this project, we created a user-friendly, easy-to-use batch registration template in MS Excel, with few mandatory and many optional variables to describe a sample, the sampling activity, location and so on. Users can easily create their Excel-template, including only the variables needed to describe a sample. In a first step, we already used the template to register water and soil samples from past expeditions and now want to extent it to and test it with further sample types.

Paleofire activity in the subtaiga of Western Siberia: natural and anthropogenic causes

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The paleofire dynamics in Russia of have been poorly studied to date, especially for the vast area of Siberia. The paper presents new results of a study of the Oshukovskoye peatbog, located in the Turo-Pyshminsky interfluve in the subtaiga zone of Western Siberia. In 3.7 m core macroscopic particles of charcoal in peat was count in each 2 sm, on the basis of which the patterns of changes in fire dynamics were analyzed during nine thousand years.
Analytical macrocharcoal results were compared with the botanical composition of peat, pollen data in the region, and the history of development of the territory according to archaeological data.
We have identified seven phases of changes in fire activity:
Phase I (8.9–4.1 ka BP): the intensity and power of fires are low, the population density is small, with appropriating type of economy.
Phase II (4.1–3.2 ka BP): there is an increase in the number of fires, but the direct connection with climate can't be traced. Phase coincides with the emergence of a producing economy, bronze metallurgy, and a population increase in the Bronze Age.
Phase III (3.2–2.6 ka BP): fire activity continues to grow, despite the cooling and raising humidity. The fire dynamics connected with the economic activity of people: the appearance of the first fortified settlements, an increase in the population.
Phase IV (2.6–2.1 ka BP): a decline in fire activity occurred, possibly due to the transition of the economy to semi-nomadic pastoralism.
Phase V (2.1-1.5 ka BP): there is an increase in fire activity, presumably this was influenced by the transition of the swamp to the oligotrophic stage. On the other hand, we revealed at that time the increase in the number of fortified settlements and a more sedentary lifestyle, against the background of reduction of large-scale cattle breeding.
Phase VI (1.5-0.5 ka BP): falls on the Middle Ages, in which multiple local military conflicts were observed, as a result, people periodically left these lands, and due to this, the anthropogenic load also decreased. Birch forests dominated at the beginning of period, later they changed to pine, which also affected the fire dynamics.
Phase VII (0.5 ka BP-now): the largest fire activity apparently due to anthropogenic factors, such as the emergence of agriculture, industry, an increase in population.
It has been established that at the local level, the frequency of pyrogenic events has a weak relationship with climate changes in heat and moisture supply. However, with an increase in the proportion of pine forests, the frequency of fires tends to increase. A direct positive relationship was revealed when comparing the intensity of fires with archaeological data and changes in the economic specifics and intensity of development of the territory.
In the future, we plan to study in more detail of paleofires dynamics in the West Siberia and will carry out investigation on various natural archive located in near human habitation area in the past.

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From biomass to fossil fuels: A contemporaneous transition to anthropogenic driven environmental changes recorded in a Central Himalayan Lake

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The timings and extent of anthropogenic impacts in the Indian Himalayas are poorly characterized, ambiguous and difficult to determine. In present study, we investigated the compositional variation, concentration, and temporal trend in the polycyclic aromatic hydrocarbons (PAHs) and fecal biomarker (coprostanol and epi-coprostanol) from the lake sediment core in the central Himalayas to determine the fate of anthropogenic activities in Himalayan ecosystems. The total concentration of PAHs (1422–32077 ng/g) and stanols (0.1–5.53 µg/g) showed an increasing trend, with the greatest values recorded after 2000 CE. In addition, the composition of PAHs changed after the 1970s, reflecting the increase in socio-economic activities in the region and the concurrent environmental change. The PAH diagnostic ratios revealed that pyrogenic sources accounted for the majority of the sedimentary PAHs. Moreover, the high correlation between PAHs and fecal stanols indicated the active role of humans in the catchment. Also, our results indicated that the total organic content (TOC%) of sediments and temperature conditions in the region play a significant role in regulating the deposition/burial of PAHs in lake sediments. In addition, based on the toxic equivalency factor (TEF) of PAHs relative to benzo(a)pyrene (BaP) (BaPeq) and sediment quality guidelines (SQGs), our findings showed an increase in toxicity with values that exceeded the recommendations for the protection of aquatic life, posing a potential toxicological threat to the lake ecosystem and the health of its human residents. As the first such study from the Indian subcontinent, this research is important/key for deciphering the molecular signals of lacustrine records from the region.

Comparison of fire and vegetation dynamics depending on human impact in the Orkhon Valley during the Late Holocene

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Mongolia presents a great variety of landscapes and climate, depending on the altitude which differs between the boreal forests of mountainous regions of the Altai in the Northwest and the steppe regions of Central Mongolia. The vegetation and fire dynamics have been impacted by both climate and human activities, which have been present there since the Upper Palaeolithic (46000 - 12000 cal. yr BP) mainly as small groups of hunter-gatherers (Tumen 2006). Since the Early Middle Bronze Age (4450 cal. yr BP) pastoralism has strongly developed (de Barros Damgaard et al. 2018; Jeong et al. 2018; Tumen 2006).
The Orkhon Valley in the Central part of Mongolia is a region of Mongolia which remains little studied with regard to past environmental dynamics. Yet it is a region of interest for study since there was a major place of life and economy, Karakorum, an ancient Mongolian capital from 1230 to 1260 AD. This represents a study of the direct impact of the activity of the Mongol Empire on vegetation and fires during this period.
Here, we aim to present the comparison of fire and vegetation dynamics of two sites over 1200 cal. yr BP. Delinn Burd (DB), located 30 km from the ancient capital of the Mongol Empire, Karakorum, which was greatly influenced by human practices and Shiret Naiman (SNN19), located more than 100 km from this ancient capital, and which has been more preserved from human activities climate and human impact at the Holocene scale.

Holocene fire history in the mid-Kama region (Urals, Russia)

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Fire chronicles and the influence of climatic and anthropogenic factors on regional fire dynamics in the context of global climate change represent a great research interest in recent years. In our DFG supported project "Plant and land use of Early Iron Age societies in the boreal zone of the mid-Kama region and its environmental impact" we focus on the history of economic development in the Urals with special attention to the fire record. Here we present a high-temporal resolution Holocene fire history in the mid-Kama region based on micro- and macrocharcoal analysis, loss-on-ignition, and radiocarbon dating of the Shabunichi-I peat core, covered the last 9200 years. Obtained results demonstrate three high-fire frequency stages corresponding to the Stone Age (9200-7400 cal yr BP), Iron Age (2300-1600 cal yr BP), and the Middle Ages. The high intensity of fires in the first half of the Holocene is probably caused by climatic reasons – the lack of archaeological data from the Stone Age of the mid-Kama region limits us in establishing the anthropogenic origin of local fires. The most intense fire events in the region are linked to the Iron Age period specifically to agricultural activities of the Glyadenovo culture, compactly inhabiting the mid-Kama valley. Archaeological finds testify the beginning of the exploration of the Kama floodplain terraces corresponding to the burning of terrace forests. At the beginning of the Middle Ages, Glyadenovo culture transformed into Nevolino and Lomovatovo cultures, and the mid-Kama was abandoned – anthropogenic pressure on regional ecosystems decreased, as evidenced by the declining intensity of fire events.

The reconstruction of Holocene northwestern Mongolian fire history based on high-resolution multi-site macro-charcoal analyses

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In palaeoecology, multi-site macro-charcoal analyses provide information on climate-fire-vegetation linkages, their spatial and temporal extent as well as the impact of prehistoric human practices. Our multi-site study comprises 8 macro-charcoal records from two highly continental forest-steppe regions in Western and North-Central Mongolia covering the Holocene. In addition to reviewing macro-charcoal influxes and comparing macro-charcoal morphotype results with arboreal/non-arboreal pollen ratios, our dataset provides the first fire frequency synthesis for two regions in Mongolia.
During the early and mid-Holocene, the fire history in Western and North-Central Mongolia is controlled by the regional climate variability, whereas the fire intensities are higher in the Mongolian Altai. In general, fire frequencies are lower in the Northern Khangai. Increases in the fire frequency correlate with the potential beginning of a rise in the nomadic population of the Mongolian Altai after 1100 cal yr BP. In both areas, individual macro-charcoal peaks, a marked site-to-site variability and a generally very low impact on the forest-steppe distribution may mostly be explained by a strictly local nomadic disturbance.

The largest forest fire in the modern history of the Czech Republic: a long-term perspective through charcoal records

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A massive forest fire that affected 1,300 hectares of the Bohemian Switzerland National Park in 2022 has sparked debate about the increasing threat of wildfires to society and nature in the Czech Republic. The question arose, is this unprecedented event outside the historical range of variability of the fire regime in the area? Charcoal records have been collected from several sites, indicating that fires have been an integral part of the long-term evolution of the forest ecosystems here, and natural regeneration is likely to result in more fire-tolerant communities.

A kaleidoscopic analysis of archival sedimentary macro-charcoal samples for reconstructing prehistoric and contemporary fire activity in South Africa

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Charcoal from sedimentary archives is widely used to reconstruct landscape vegetation-fire relationships from modern and ancient landscapes. Digital image analysis is speeding up measurements of sedimentary macro-charcoal, (i.e., grains or particles > ~125—10 000µm). Fire reconstructions now boast higher spatial, temporal, and stratigraphic resolutions. Also, the scope of charcoal analysis has widened to include the determination of fuel-related metrics. However, the reliability and consistency of charcoal metrics across different laboratory processing methods remains untested. There is also underlying variation in how researchers quantify charcoal. Neglecting the study of these key variables may compromise the robustness of charcoal interpretations. Therefore, this initiative funded by the Past Global Changes Inter-Africa mobility grant (PAGES-IAM) aimed to achieve a re-analysis of fire-fuel-type-biomass relationships from charcoal metrics from grassy ecosystems across grazing density, climate, and temporal gradients. We conducted supervised and unsupervised charcoal edge-detection analysis of matched archival imaged samples using Chartool v.1 to from three laboratory methods. We plan to present our preliminary results and discuss how they relate to previous multi-proxy interpretations. We hope to extend this study by developing more training datasets to assist bulk machine-based object-based image analysis (OBIA) to quickly fingerprint the diversity of local and landscape fire regimes from grassy ecosystems

Glacial-interglacial fire-vegetation-climate feedbacks of the high-northern latitudes: what Lake El'gygytgyn, NE Siberia, has recorded

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Forest fires in the Siberian Arctic get larger, hotter and the fire season gets longer, which raises concerns if these fires might lead to biome shifts from tundra to summergreen or evergreen boreal forest – with consequences for regional to global biophysical land properties and biogeochemical cycles. Given the short time span of instrumental observations, it is unknown if fire can initiate or support biome shifts under the ongoing amplified warming or if climate drives fire regime and biome changes independently. Lake El'gygytgyn in the Russian Far East is currently surrounded by tundra, but for example, during late marine isotope stage (MIS) 12 and "superinterglacial" MIS 11, c. 375-440 kyrs ago, pollen data suggests that biome composition changed several times – from a glacial steppe to interglacial summergreen and evergreen boreal forest. In a DFG project, we investigate fire regime shifts during previous warmer-than-present interglacials, such as MIS 5e, 11c and MIS 101-104, and ask if and which type of fire regime shifts accompanied biome shifts in the East Asian high latitudes.

To enable a quantitative reconstruction of changes in fire intensities and the type of biomass burnt, we analyzed multiple fire proxies. The monosaccharide anhydrides (MAs) are specific biomass burning residues from low-temperature fires analyzed with ultra-high-performance liquid chromatography coupled to a high-resolution mass spectrometer. Sedimentary charcoal reflects mid-to-high intensity fires and was analyzed in sieved fraction > 150 m and from pollen slides using classical microscopy. MA isomer ratios and charcoal morphotypes were used to reconstruct the type of biomass burnt. We analyzed fire proxy amounts and composition and updated existing pollen-based vegetation reconstructions for the early and late Pleistocene using sediments from ICDP sediment core 5011-1 and compare that with fire proxies in modern lake surface sediments from three, modern-analogue lakes in Eastern Siberia.

We find clear differences in sedimentary fire proxy composition over time, with modern compositions depending on source area of charcoals and MAs. Modern fire-vegetation-relationships are linkable to past interglacial proxy relationships indicating that fire regime change played a role during some, but not all biome shifts. More in-depth analyses of the multiple fire proxies with identify the background conditions for that. Overall, this new understanding of Siberian sedimentary fire proxies is crucial for a sound, i.e. quantitative reconstruction of long-term fire regime change, to assess the role of fire regime intensification in biome changes during periods of stark warming.

The Global Paleofire Database - past, present, future

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The Global Paleofire Database (GPD) is a product of former PAGES Global Paleofire Working Groups and was also known as "Global Charcoal Database, GCD". It gathers sedimentary charcoal records from all over the globe in a accessible repository and is a community effort, mainly compiled for large-scale data syntheses projects.
Here, we present its history, current relevance and potential future pathways under the umbrella of the International Paleofire Network (IPN), a network open to everyone to develop paleofire-related projects, and as a new Constituent Database of the Neotoma paleodata repository. We aim to stimulate discussion on how to include further paleofire proxy records (not only charcoal) to gain deeper understanding of past fire properties, drivers and impacts, and to address new regions that currently lack paleofire data.

Palaeoecological signals for Mesolithic Land Use in a Central European Landscape?

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The Early Holocene is characterised by a set of climatic factors responsible for natural environmental fires. However, it is still debated whether humans also co-shaped the landscapes using fire in the Mesolithic period (~11.5–7.4 cal ka BP). Hypotheses on the anthropogenic fire impact during the Mesolithic period are often considered, but detailed, local scale, and well-dated paleofire-records linked with corresponding Mesolithic sites are still rare.
High-resolution, multi-proxy studies on the Ammer Valley palaeo-wetland, SW Germany, included pollen, micro- and macrocharcoal, and plant macro-remains together with archaeological evidence from Early and Late Mesolithic sites of Rottenburg-Siebenlinden. This multi-proxy approach was the key to understanding the link between palaeoecological records and Mesolithic land use strategies. The results suggested that rigorous natural fires strengthened the endurance of open and pioneer vegetation between 11.6-10.6 cal BP. The region became more and more attractive to hunter-gatherers between 10.6-9.5 cal BP. This was also related to the shift from a river-dominated environment towards a wetland with open stagnant waters where a diversity of plant resources (incl., hazel) were available. In the Ammer Valley, the Mesolithic population may have manipulated the environment by means of fire, attempting to promote open vegetation to reinforce their subsistence strategies from 10.1 cal BP onwards. Subsequently, up to 9.5 cal BP the multi-proxy records showed frequent low-intensity fires and vegetation disturbance coinciding with the Mesolithic occupation phases, suggesting certain anthropogenic control over fire.

Using past analogues to understand role of fire and climate change in Central Indian forests

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The nature of the relationship between fire and climate change is yet to be fully understood, especially in arid ecosystems. Our current scientific understanding states that higher the length, frequency, and severity of a dry season, higher the chances of biomass burning, further increasing the likelihood of warm and dry periods that are already projected in the near future. The degree of fire–aridity coupling, however, varies across ecosystems around the world, underlining the importance of investigating the role of fires in a regional context and its implications on forest ecosystems. Here, we bring a case study from the central part of the Indian Subcontinent, where fires, despite being a pressing social-ecological issue, are seriously understudied. As WWF attests, dry deciduous forests of Central India spread across 1,43,551 km2, host the country's most Protected Areas (including tiger reserves), while supporting the livelihoods of millions. Over the last few decades, it is observed that nearly 10,000 km2 of Central Indian forests burn each year, at a frequency that has been detrimental to biomass and species diversity with social-ecological implications. The Forest Departments in India have been investing significant resources in managing fires - often restricting them -, instigating conflicts with local communities relying on low-frequency fires on agricultural lands close to PAs. We argue that understanding the long term fire regimes is imperative in identifying a "natural" fire regime in the Central Indian forests, i.e., the threshold of fire frequency and intensity that would not alter the ecosystem, rather aid in forest fire management through inclusive means. Drawing upon new, high-resolution multi-proxy (pollen, charcoal, carbon isotopes) paleo-records merged with spatially explicit ecosystem modelling (plant fire–resistance traits), we untangle the impacts of fire–climate coupling on forest species composition in Central India. A combined proxy-modelling approach will help unravel the dynamics of species composition and environmental factors including fires, precipitation and temperature changes in the region. Our efforts will, in turn, bring empirical evidence for ecosystem-specific policy implications, better equipping Central Indian landscapes against adversities associated with climate extremities. Our work is supported by Government of India SERB-Power Grant No.SPG/2021/000860.

In search of Early Neolithic fires in prehistoric soil archives in the Silesian loess zone (SW Poland)

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The spread of a sedentary lifestyle and agricultural economy during Neolithic period, is considered a turning point for human impact on the environment in Central Europe. Early Neolithic (late 6th mill. – early 4th mill. BC) settlement in Silesia (SW Poland) was limited to areas with a loess-derived soil cover, where the landscape was transformed by vegetation clearance and establishment of a network of villages, fields and pastures. It is widely assumed that these 'pioneering' activities relied heavily on the use of fire. It was also suggested that large-scale burning and the resulting input of carbon particles, contributed significantly to long-term processes, such as the formation of chernozemic soils in Central Europe.

Since there is a general lack of sediment traps such as lakes and bogs/mires in the loess zone in Silesia, to obtain material for paleoenvironmental reconstructions, we studied original, Neolithic soils buried and preserved beneath four barrow mounds (built ca 3500 BC) discovered in the Muszkowice and Głubczyce Forests. All four paleosols were classified as Phaeozems, what is especially noteworthy, as the prevalent present-day soil cover in the region consists of Luvisols.

The results suggests a widespread presence of chernozemic soils, which dominated in the open, forest-steppe Silesian landscape at the onset of the Neolithic (late 6th mill. BC) and persisted well into the Late Holocene. The investigated paleosols delivered proxy data related to prehistoric agriculture (crop growing), as well as evidence of the use of fire – most likely for in situ vegetation clearance. Nevertheless, it remains difficult to assess the specifics of the applied burning regimes: whether they were 'multi-episode', 'intensive' or 'large-scale'.

At present, we can indicate that: 1) it seems unlikely that Neolithic fires contributed directly (by addition of carbon particles) to the formation of chernozemic soils in Silesia, however, 2) the sustainment of 'open', agriculturally used landscapes was crucial for the persistence and preservation of chernozemic soils during the Neolithic (in the Atlantic period).

Fire dynamics in high-diversity beech forests in the Eastern Carpathians

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Over the past decades, large and uncontrolled wildfires have occurred in all terrestrial ecosystems. Global warming may amplify this trend and threaten most ecosystems worldwide for the next decades. Alterations of fire regimes may affect fire-prone systems and forest ecosystems that have not historically experienced fires, such as the European beech forests. Understanding the long-term dynamics of these high-plant-diversity beech forests is crucial to anticipate changes in these ecosystems in the ongoing global warming. This study aims to understand how European beech forests have colonized inner Eastern Carpathians (Slovakia) and the main factors explaining their high biodiversity.

We applied a multi-proxy approach involving charcoal, pollen, and macrofossil analyses. We used palynological richness, evenness, and turnover variation compared to the charcoal peak detection analysis.

Low-diversity spruce forest was dominant until 5200 cal. BP during a fire-prone period mainly due to climatic conditions. The establishment of late-successional, shade-tolerant *Fagus sylvatica* was facilitated by fire disturbances, but its expansion coincided with major gaps in fire events from 3900 cal. BP. The palynological richness has increased during the transition from spruce to beech forest, highlighting the importance of beech forests in maintaining plant biodiversity. However, the stronger increase of the richness is synchronous with the increase in human activities around 2000 cal. BP, and then 350 cal. BP.

Low-frequency fires have been a natural driver of vegetation changes in the Carpathians by promoting the emergence of highly diversified beech forests. However, human impact has later also shaped these landscapes.

Mediterranean trait response to fire gradient

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For the next decades, climate in Mediterranean region is expected to be 25% warmer over the year than the rest of the planet, likely causing higher fire risks, longer fire seasons and more frequent, large, and severe fires. Understanding the processes shaping plant communities under fire is a core challenge in ecology and conservation science in this area: Is there a scheme of plant trait distribution and functional diversity in response to a gradient fire number and size in a Mediterranean ecosystem?
The results show no direct significant relationship between fire parameters and plant species. At the community level, however, the trait values narrowed to maximizing the efficiency of traits in a highly fire prone systems. In addition, seed mass, and wood density are closer to fire parameters in bidimensional PCA analysis than LNC and SLA variables.

Postglacial fire and vegetation dynamics of the East-European forest-steppe

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Climate change is one of the most challenging problems facing humanity. Depending on climate conditions and vegetation composition, a fire regime changes threat previously relatively fire-free regions. East-European forest-steppe is an economically important ecotone between arid steppe and mesophilic forest. To assess the possible fire risks induced by the current climate warming we conducted a study on the past vegetation and fire dynamics of the central and southern parts of the East-European forest-steppe. Two sediment cores covering the last ~14.8 and 9.8 thousand years were studied for pollen, non-pollen palynomorphs, botanical macro-remains, macro- and micro-charcoal. Using modern analogue technique, we reconstructed forest cover to examine its correlation with the wildfires' frequency and intensity and the potential climate forcing. Micro- and macro-charcoal concentration and influx were low during the Late Glacial (14.8–12.5 cal. kyr BP), suggesting low fire activity. Fire activity strongly increased during the Younger Dryas and the early Holocene, corresponding to spread of pine forest-steppe. Charcoal loads decreased at ~7 cal. kyr BP possibly due to the decrease in forest cover and/or a change in forest composition. After the development of the mixed-broadleaf forest-steppe ~4.2 kyr BP, local forest wildfires were no longer detected. Charcoal maxima in the late Holocene are strongly related to the increased human impact.

Reconstructing the Early to Late Holocene fire events in the vegetation of the Zenne Valley, Central Belgium

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Fires are an important factor in the shaping of ecosystems and are closely related with climate change, vegetation and, especially in more recent times, human action. Charred particles in sedi-ment cores are widely used as proxies for the reconstruction of fire histories, with the ultimate goal of revealing the local paleofire history of certain catchment. In this project we examined the a peat core from the Zenne Valley in Brussels that, according to radiocarbon dating, corresponds to the time span of Early to Late Holocene. Since data on the pollen content of the studied core were available as well, we carried out a comparison between fire history and the reconstructed vegeta-tion of the research site. The macroscopic charcoals from this sediment record were used to doc-ument the long-term local fire activity in the last ca. 10 000 years. The fire frequencies showed several pronounced peaks, situated around 8000 BP. The high consistency with increasing tempera-tures at this period indicates climate as a major driving factor, confirmed by the correspondence with other charcoal records from Northwest Europe. The results demonstrate the role of fuel build-up by pine and suggest fire-vegetation interactions associated with a pronounced fire event at 8000 BP. The Mid Holocene is characterized by a general decrease in fire frequency, but the sec-tion shows also peaks in fire activities around 7000, 6000 and 5100 BP. The time between two con-secutive fire events seems to remain constant, although the fire frequency gradually decreases between 7000-4200 BP from ca. 2 fires to 0 fires per 1000 years. Subsequently during the Late Holocene a rather quick increase in fire frequency is visible characterised by the occurrence of four fire evets per 1000 years from 3400 BP onwards and fire magnitude peaks, that can be seen at ca. 3400, 3200 and 2700 BP. The local paleofire signal of the Zenne valley is comparable to the paleofire trends from North-Western Europe indicating a link between biome types and fire activi-ty in the Early Holocene and asynchronous pattern in the Late Holocene.

Vegetation dynamics and fire history in permafrost area of Central Siberia during the last 7000 years

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Recent climate change in Siberia is increasing the probability of dangerous forest fires. The development of effective measures to mitigate and prevent fires is impossible without an understanding of long-term fire dynamics. We present the new multi-site palaeo-fire reconstruction based on macroscopic charcoal data from 16 peat and lake sediment cores located in different landscapes across the permafrost area of Central Siberia. The studied sites are situated in three model areas: the Putorana Plateau, the middle part of the Central Siberian Plateau (Lower Tungiska River basin, near the settlement of Tura) and the marginal part of West Siberian Lowlands (Yenisei River basin, near the town of Igarka). Charcoal records cover the last 7000 years. We used the Paleofire R package version 1.2.4 as the standardization technique of the obtained data to compare the local fire reconstructions from the study area. The composite cureve of biomass burning was compared with pollen and plant macrofossil data, reconstruction of total forest covarage by best modern analogue technique and July temperature reconstructions. The obtained results show similar temporal patterns of charcoal accumulation rates in the cores under study, and near synchronous changes in fire regimes. The paleo-fire record revealed moderate biomass burning between 7.0 and 5.9 and between 3.4 and 2.6 ka BP. The periods of lowest fire activity occurred in 5.9-4.2 and 2.6-1.5 ka BP, that coincided with regional climate cooling and moistening, and reduction of forest vegetation in the study regions. Charcoal accumulation rates increased to the mean values during the interval from 1.5 to 0.8 ka BP and appears to be partly synchronous with climate warming during the Medieval Climate Anomaly. Frequent fires may encourage local permafrost to thaw, creating better conditions for tree growth and regeneration, and likely favouring spruce expansion. Since 0.8 ka BP charcoal influx raised and exceed the main value until the present time. With exception of charcoal records from the Putorana Plateau the decrease of fire frequency during the Little Ice Age revealed from tree-ring data from Central Siberia was not recorded by the charcoal data from peat cores. Fire frequency and charcoal accumulation increased abruptly during the last 150 years, obviously due to human impact. Regional reconstructions of long-term fire history show that recent fires are unprecedented during the middle and late Holocene, with modern high biomass burning lying outside millennial and centennial variability of the last 7000 years.

The role of fire in the Medieval and Early Modern landscape of Bad Waldsee within the broader context of the pre-Alpine forelands of South-Western Germany

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Fire, an important element of human land use strategies, was part of many early industrial activities but also of burning incidents that significantly impacted settlement structures and development. The spatial proximity of the historically well-documented medieval town and sediment archive deposited in its central lake (Stadtsee) was taken to investigate the interplay of fire and socio-environmental developments during the preindustrial phase of 750-150 B.P. (1200-1800 AD). The burning episodes were detected using sediment macroscopic charcoal record (>150 µm) and were interpreted considering sedimentological, palynological and historical evidence. Macro-charcoal analysis revealed two main phases of biomass burning: a late Medieval one (653-533 cal B.P.), followed by a distinct fire-free interval, and a second Modern Times phase (313 cal B.P. until today). During the late Medieval times and after 1750 AD (200 cal B.P.) low-magnitude local fires coincided with high-intensity land use pressure. Major historical events like the Thirty Years' war and the fire incident near the town (1386 AD - 174 cal B.P.) were also documented by the charcoal sedimentary record. The specific terrain morphology and the town microclimate impacted the chance, if certain local burning patterns were detectable at all. The present results demonstrate that during the Medieval period to the present day, fire events, mainly anthropogenic, were coupled with the main vegetation developments. Anthropogenic fire was an inseparable part of the Bad Waldsee landscape . as also recorded historically by the town archives.

Assessing changes in global fire regimes via expert elicitation

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One of the most visible ways humans are affecting the environment is our modification of wildfires. Nearly every type of human activity influences wildfires, including agriculture, spreading invasive species, and changing the climate, creating serious consequences for human societies and their environment. However, predicting fire interactions with land use, management, and climate change, remains challenging and represents a serious knowledge gap and vulnerability. In our study, we surveyed 98 wildfire researchers from around the globe for a holistic assessment of how fire regimes are changing and what this could mean for human society, global biodiversity, and climate change. We asked for quantitative and qualitative assessments of the frequency, type, and implications of fire regime change from the beginning of the Holocene through the year 2300. Respondents indicated that direct human activity was already influencing wildfire locally since at least ~12,000 years BP, though natural climate variability remained the dominant driver of fire regime until around 5000 years BP. Responses showed a ten-fold increase in the rate of wildfire regime change during the last 250 years compared with the rest of the Holocene, corresponding first with the intensification and extensification of land use and later with anthropogenic climate change. Looking to the future, fire regimes were predicted to intensify, with increases in fire frequency, severity, and/or size in all biomes except grassland ecosystems. Fire regimes showed quite different climate sensitivities across biomes, but the likelihood of fire regime change increased with higher greenhouse gas emission scenarios for all biomes. Biodiversity, carbon storage, and other ecosystem services were predicted to decrease for most biomes under higher emission scenarios. We present recommendations for adaptation and mitigation under emerging fire regimes, concluding that management options are seriously constrained under higher emission scenarios.

Reconstruction of forest fires in the Nizhnyaya Tunguska river basin (Central Evenkia) in the middle and late Holocene from the data of the macroscopic charcoal analysis in peat

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The periodicity of fires in the Middle and Late Holocene in the vicinity of the village of Tura (central Evenkia) is considered according to the analysis of the concentration of macroscopic coal particles in peat bogs: Gornoye (64°13'55.97"N, 100°02'5.21"E) and Nizhnyaya Tunguska (64 °10'49.74"N, 100°34'59.16"E). The depth of the deposit of the Gornoe swamp is 215 cm, radiocarbon dating at the base of the well is 7015±25 14 BP. (IGANAMS 9531), Nizhnyaya Tunguska 113 cm and 6785±25 14C BP (IGANAMS 9525), respectively.

Sample preparation for the analysis of coal macroparticles was carried out according to the standard procedure 1. Samples from the Nizhnyaya Tunguska bog were also counted by analyzing photographic images using a program written in the R language. As a result, it was possible to determine particles > 250 µm2 with an accuracy of 71%. The Pearson correlation between the samples calculated by the standard and software methods was 84.5%. The tapas software package in R was used to highlight fire events.

A comparison of the data obtained on the frequency of fires and climatic reconstructions for the north of Siberia showed that the period with low fire activity in Central Evenkia in the interval between 7900 and 3700 cal. BP comparable in time with warming and an increase in moisture by more than 140 mm at a latitude of 60-65°N in the Middle Holocene. C 3700 to 2700 cal. BC, a high frequency of fires in the study region was revealed, which is in good agreement with the interval of precipitation decrease according to the reconstruction made according to palynological data from the lakes of Taimyr. Cooling and humidification of the climate of the Northern Hemisphere starting from 2500-2700 cal. BP led to a decrease in the frequency of fires in Central Evenkia in the Late Holocene. The accumulation of coal macroparticles in bog sediments increases in the 17th century, and may be due to the anthropogenic factor. According to data from the Gornoye swamp, several fires were identified, which occurred on average once every 105 years.

The study was supported by the Russian Science Foundation project 20-17-00043

1) Mooney S.D., Tinner W. The analysis of charcoal in peat and organic sediments. Mires and Peat, Article 09, 2011, 1–18.

Utilizing paleoecological reconstructions to inform fire-disturbance restoration and land management

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This study examines sediments from Deep Creek Lake (DCL) to reconstruct the past vegetation, climate and disturbance regimes for the area. DCL is located on Thousand Lakes Mountain in southern Utah. This high-elevation lake (approximately 3,200 meters) will provide a local record of environmental change for most of the Holocene. The lake core from this site produces a 9,000-year-old record which will offer insights about the Holocene climatic optimum and how the ecosystem and its fire regime reacted to considerably increased temperatures in the past. This study will reconstruct a palaeoecological record of pollen, charcoal, stable light isotopes (15 N, 13 C) and XRF (x-ray fluorescence-elemental) data to quantify how fire disturbances impact vegetative and biogeochemical cycling patterns of the past to forecast the future. These findings will be used to guide the development of resilient land management practices that account for rising temperatures yet seek to minimize the damage and sustain the biodiversity of natural areas for generations to come.

Deep Creek Lake promises to provide an interesting record, since it has experienced volcanic activity, is currently adjacent to active rock glaciers and its' own aspen clone. The research done at Deep Creek will contribute to the findings of the Fish Lake basin and the giant Pando aspen clone. We are interested in the regional implications of these findings and will collaborate with scientists conducting similar work within western North America. We work closely with representatives from the National Forest Service and United States Geological Survey to determine the most proactive and sustainable forestry and conservation protocols. The goal of this research study is to recognize patterns of the past to anticipate ecosystem changes in the future, and to apply these discoveries to advise land management in a manner that protects the biodiversity of these natural areas and our dependence on them.

Workshops and Field trip

Trends and Peaks analysis in R with the 'tapas' package

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The set of functions gathered in the tapas R-package (https://github.com/wfinsinger/tapas) is meant to be used for analyzing paleoecological records when the goal is to estimate the long-term trend and identify peaks to reconstruct the occurrence, the return intervals, and the magnitude of distinct events. The package heavily builds on CharAnalysis, a software for analyzing sediment-charcoal records written in and compiled with Matlab.
Two main reasons led to the development of tapas. Firstly, as R is an open source product, modifying the software to suit individual needs may be more straightforward. Secondly, an integration and inter-operability with other already existing R-packages may allow using trend and peak-detection analysis in conjunction with other workflows. These may include both workflows involving single site records as well as workflows making use of large sets of records through connections to open-access databases.

Neotoma workshop

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We will introduce you to the Neotoma environment including explorer, Tilia and the Neotoma R package. The database uses API (application programming interface), which serve the explorer as well as Tilia but also let you query the database in R. We will show you which information you can most easily extract in either of these choices and provide a hands on R exercise on working with charcoal and pollen data.
https://www.neotomadb.org/

Preparation of the Neotoma workshop

At the workshop we want to give you an introduction of how to interact with the Neotoma database using 3 out of 4 possible ways:

1) introduce the functionality of the Neotoma explorer.
2) show how to get most out of Neotoma using Tilia.
3) give an appetizer on how to work with the neotoma2 R package.

If you would like a hands on experience following our examples, we kindly ask you to have the following ready:

1) Bring your computer.
2) Install a recent version of Tilia preferably the full version that can be obtained by following a link on the Neotoma webpage: https://www.neotomadb.org/apps/tilia under installing Tilia. The link will lead you to a web form where you are asked to provide some personal information. After submitting the form an automated email will be sent to you with the installation instructions. Please check your spam folder if you don't receive one.
3) Make sure you have the most recent version of R and R-Studio on your computer and install the following packages: dplyr, rioja, riojaPlot, vegan and neotoma2. Note that neotoma2 needs to be installed from GitHub:

Install packages

devtools::install_github('NeotomaDB/neotoma2')
here: you will also need devtools if you don't have it

Also riojaPlot is not yet a CRAN package and you need to install it like this:
install.packages("riojaPlot", repos="https://nsj3.r-universe.dev") or
remotes::install_github('nsj3/riojaPlot', build_vignettes=TRUE, dependencies=TRUE)

Field trip to Harz mountains: Impact of mining on vegetation and environment

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The Upper Harz was one of the most important mining regions in Germany. Smelting of copper ores from the Harz probably started during the Bronze Age. Copper, silver, lead and iron ores were widely used especially during the late Middle Ages. The ores were taken to heavily forested areas for smelting, since far larger quantities of charcoal than ore were required for smelting. This meant that mining quickly had an impact on the forest in the Upper Harz. The fieldtrip will present some insights into the mining industry in the Harz Mountains and its impact on the vegetation.
The first stop will be the Samson Pit, located in Sankt Andreasberg. It is counted among the most significant mining monuments in Europe. From 1521 until 1910, silver ore in particular was mined here. The Samson Mine is part of the Upper Harz Water Management System, which was declared a World Cultural Heritage Site by UNESCO in 2010. Here we will provide you information on impact of mining on the vegetation evidenced by charcoal and pollen records from mountain region.
Afterwards we will go to the lakes Juessee and Seeburger See located at the foothills of the Harz. Here we will present vegetation history of the region since the late glacial.
Start: 9 a.m. at the parking of Faculty of Geoscience and Geography
Costs: c. 10 Euro for museum entrance in Samson Pit.
Finish: about 2 p.m.

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