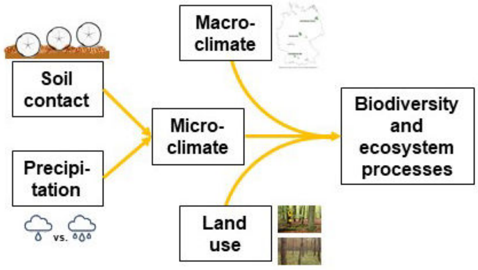
BEClimWood Experiment – Effects of climate and land use on wood decomposition, biodiversity in deadwood and wood-soil interactions

Summary:
Aim: test interactive effects of land-use intensity and climate across scales on biodiversity and ecosystem processes in deadwood and at the deadwood-soil interface
Approach: experimental manipulation of soil contact and precipitation during growing period for deadwood logs of two tree species at 27 VIP plots spanning gradients in land-use intensity and macroclimate



Background:

Deadwood is a key component of carbon and nutrient cycles in forests and habitat for ~30% of all forest species (Stokland et al., 2012; Ulyshen, 2018). It can affect processes in the soil (Minnich et al., 2021), store water (Błońska et al., 2018), and create patches of altered soil and forest functioning (Stutz & Lang, 2023). Decomposition rates and associated species communities in deadwood differ strongly between tree species and between climatic regions, and they are affected by forest structure (e.g., canopy cover) and forest composition (e.g., conifer share) associated with land-use intensity (Edelmann et al., 2023; Gossner et al., 2016; Kipping et al., 2022; Moll et al., 2024; Rieker et al., 2022).

Since its establishment in 2009, the Biodiversity Exploratories long-term Deadwood Experiment (BELongDead) has served as a platform for studying the effects of tree species (13 different species) and forest structure associated with land use on decomposition processes and biodiversity of various taxonomic groups. Now, most of the logs have reached a final stage of decomposition and most sampling is coming to an end. While the BELongDead experiment improved our understanding regarding the role of tree species and land use as drivers of biodiversity and decomposition (>30 published papers), it also raised new questions, such as how do microclimatic differences between logs affect decomposition rates and biodiversity?

Microclimatic conditions, i.e., temperature and moisture content in deadwood, are major drivers of wood decomposition rates and biodiversity at global and regional scales (Bradford et al., 2014; Seibold et al., 2021). Even at local scales, differences between logs within the same forest stand and within individual logs are often attributed to variation in microclimate related to forest structure and soil contact (Kipping et al., 2022; Woodall et al., 2020). Yet, the overall role of microclimate and whether microclimatic effects differ depending on macroclimatic conditions or forest stand characteristics associated with land use remains open. Considering global climate change, a better understanding of the interactive effects of climate across scales and land use on biodiversity and decomposition processes of deadwood is urgently needed to make predictions on how they will change ecosystem functions (incl. carbon sequestration; Stutz, 2023). Moreover, decaying deadwood can store water and can affect microclimatic conditions and soil processes depending on site conditions (Stutz et al., 2019). This function will likely become more important as temperatures increase and precipitation decreases, yet our understanding of these processes in deadwood decomposition is very limited. Studying effects of climate change using natural variation in weather conditions between years in longer time series is not possible for deadwood since biological communities and chemical and physical characteristics in deadwood undergo clear succession and thus, comparing patterns between years with different weather conditions is impaired by differences in decay stage (Pichler et al., 2012; Seibold et al., 2015). Therefore, controlled experimental manipulations are needed to study climate-change effects for this system.

Objectives and experimental design

Based on the experiences and new questions raised by the BELongDead Experiment as well as on general advances in this research field and the increasingly apparent effects of climate change, a new long-term deadwood experiment for the Biodiversity Exploratories has been designed. The overall objective of this new experiment is to gain a better understanding of how **land use and climate at different scales interactively drive biodiversity and processes** associated with deadwood. The design of the experiment (Fig. 1) addresses effects of land use and climate considering climate in three different ways:

- **Soil contact manipulation**: Microclimate within deadwood is largely determined by soil contact, which varies from almost no contact (e.g., standing deadwood or complete downed trees) to complete burial of belowground deadwood depending on ecosystem processes and management. Logs in greater contact with the soil have higher moisture content and lower temperatures. At each plot, one third of the experimental logs will be placed on the ground with full soil contact, one third will be placed on stones to limit soil contact and one third of the logs will be partly buried to have elevated soil contact. This third treatment also represents belowground woody debris, a hitherto understudied type of deadwood (Moroni et al., 2015).
- **Climate-change treatment:** Reduced precipitation during spring and summer, as predicted by climate-change projections for Central Europe(Samaniego et al., 2018), will be simulated using rainout shelters. One log of each soil-contact treatment per plot will be placed under a **rainout shelter** which reduces throughfall (i.e., precipitation minus interception by canopy) by 50%. The same set of logs will be placed under **control shelters** which do not affect throughfall, but provide similar conditions as the rainout shelters (e.g., light transmission, wind chill). The design of the rainout shelters will be similar to those used for the DroughNet experiment (Pangle et al., 2012) using equally spaced troughs (half-cut pipes) placed approx. 1.5m above ground which collect rain and divert it away from the logs. Control shelters use the same structure but troughs are inverted, so rain is not excluded. Troughs are installed each year between April and August and removed for the rest of the year. In addition, the rainout shelter manipulation allows testing how much and how fast deadwood logs lose water during rainfall exclusion and how long it takes to take up water after rainfall exclusion ends.
- **Regional climate:** The experiment will be repeated in all **three regions of the Biodiversity Exploratories** which represent a gradient of increasing temperature and decreasing precipitation from Swabian Alb to Hainich and Schorfheide. This will allow studying how macroclimate mediates effects of microclimate and reduced precipitation on biodiversity and processes associated with deadwood.

The experiment will be conducted at **30 VIP plots** (where possible, the same as the BELongDead experiment) covering **gradients in land-use intensity** from unmanaged beech forest, to managed beech forest to managed conifer forest. This land-use gradient represents simultaneous changes in forest structure, e.g., canopy cover, and tree species composition typical for Central European forests (Schall et al., 2018). The experiment will be conducted for **two tree species** – one angiosperm tree species (*Fagus sylvatica*) and one gymnosperm tree species (*Pinus sylvestris*) representing the two major clades which differ in biodiversity and decomposition processes. Each plot will therefore receive 12 freshly cut logs (2 tree species x 3 soil contact treatments x 2 climate-change treatments) making a **total of 360 logs**. Logs will have a **diameter of approx. 30 cm and 2.5 m length**. Logs will be obtained from trees felled in autumn/winter 2025/2026 and placed at the experimental plots before the start of the growing period 2026.

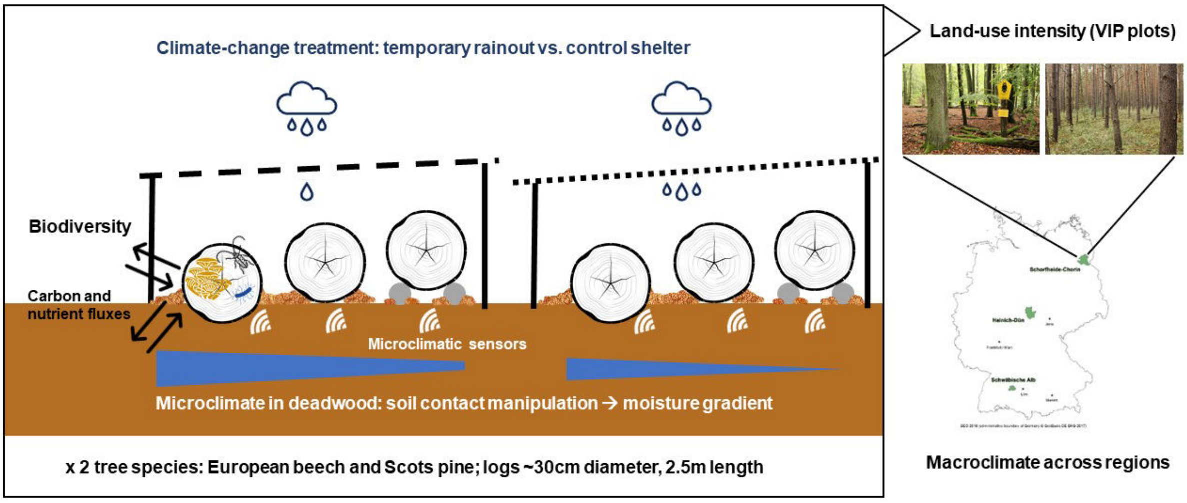


Figure 1: Visualization of the experimental design of the BEClimWood Experiment including local manipulation of soil contact and throughfall which is replicated along land-use intensity gradients and the three regions of the Biodiversity Exploratories.

Novelty and key questions

The key novelty of BEClimWood is that local experiments are replicated along gradients in land use and macroclimate which allows the interactions between the effects of land use, macroclimate, microclimate and simulated climate change for biodiversity and ecosystem functioning to be tested. Particularly for the climate-change experiment using rainout shelters, the combination of manipulation and control treatments with gradients in macroclimate across regions and microclimatic differences between forest stands associated with land use (e.g., higher vapor pressure deficit in stands with less dense canopy; Thom et al., 2020) represents a major advance as requested by recent reviews (Hoover et al., 2018; Knapp et al., 2024). This approach allows for a more mechanistic understanding of the processes at play, such as the interactions and feedbacks between deadwood, soil and forest stands (e.g., drivers of wood moisture; Green et al., 2022). Specific research questions and hypotheses include:

Effects of soil contact and associated deadwood microclimate:

- How important is soil contact affecting microclimatic conditions in deadwood for biodiversity and ecosystem processes?

- Is the role of soil-contact related microclimate for deadwood differing between land-use intensities? E.g., soil contact has stronger effects on biodiversity and decomposition processes in managed sites with a more open canopy than in unmanaged sites.
- Is the role of soil-contact related microclimate for deadwood differing between macroclimatic regions? E.g., the importance of moisture content biodiversity and decomposition processes decreases with increasing precipitation across regions.

Effects of climate-change treatments:

- How is reduced throughfall affecting biodiversity and ecosystem processes?
- Are the effects of reduced throughfall differing between macroclimatic regions? E.g., effects are stronger in regions with low precipitation as very low deadwood moisture may cause shifts in biological communities.
- Are effects of reduced throughfall depending on soil contact? E.g., effects could be buffered for deadwood with soil contact and thus higher water content.
- Are the effects of reduced precipitation differing between different land-use categories in forests? E.g., effects could be stronger in managed sites with lower canopy cover and thus higher vapor pressure deficit.

Potential measurements conducted by core and contributing projects include:

- Temperature and moisture content in deadwood as well as in the underlying soil
- Community composition, diversity and biomass of biological communities, particularly insects, fungi and bacteria
- Trophic interactions and nutrient fluxes across decomposer food webs
- Deadwood decay rates
- Carbon and nutrient fluxes between deadwood and the underlying soil
- Radial gas concentration (CO_2, O_2, CH_4) in deadwood
- Microbial metaproteomics

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