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Carbon flux, energy balance and vegetation change of a recently restored forest peatland in the Solling mountains, Germany

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Peatlands represent the most space-effective and largest terrestrial carbon sink, delivering multiple crucial ecosystem services. In contrast, drained peatlands have been identified as hotspots of greenhouse gas (GHG) emissions and constitute a relevant climate factor. Projections suggest that, due to severe human impacts, peatlands worldwide will shift from a global net GHG sink to a source in the near future, causing positive radiative forcing. Restoring peatlands therefore constitutes an effective and relevant nature-based climate change mitigation measure. However, effects of drainage and afforestation on temperate peatlands are still uncertain, and data on multi-year carbon exchange rates between recently restored afforested peatlands and atmosphere of Europe's low mountains are non-existent.

Here we analyse 2.5 years of eddy covariance flux measurements of carbon dioxide, methane, sensible and latent heat of a clear-cut forest peatland during early stages of restoration in the Solling region, Lower Saxony. We found large amounts of carbon to be released from the peatland to the atmosphere in the first years after the implementation of restoration measures. This is due to extraordinarily high ecosystem respiration rates that cannot be compensated by gross primary productivity and are clearly regulated by moisture conditions of the peat. Calculations of GHG fluxes were complemented by UAV flights, geophysical measurements, soil analyses and vegetation surveys to disentangle the spatio-temporal variability of influencing factors. We related results of repeated electrical resistivity tomography to soil properties and discuss the effects of their spatial heterogeneity on gas fluxes. True colour orthophotos obtained from repeated UAV flights were used to delimit vegetation units and changes in plant composition with ongoing plant succession. Based on variations in heat capacity of different matter, thermal images were used to assess fine-scale differences in soil moisture to evaluate their potential to model and upscale spatio-temporal trends of thermal characteristics and ecosystem respiration in unprecedented detail. Finally, we evaluate underlying factors of GHG fluxes, discuss implications of restoration measures and outline potential future developments.

To allow for careful consideration of restoration measures in temperate peatlands formerly drained for forestry, the benefits of restoration must be contrasted with the initial investments and future losses when the land is taken out of economic production. Outcomes from this study

will provide the needed insights into forest peatland restoration and its associated processes in temperate peatlands.