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Mapping soil CO2 efflux to identify hot spots in temperate peatlands based on UAV remote sensing

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The emission of CO_2 from peatlands varies significantly across space and time which renders accurate quantification and modeling of carbon fluxes challenging. In this study, we combined in-situ measurements with Unmanned Aerial Vehicle (UAV) remote sensing (RS) to investigate soil respiration patterns across a temperate peatland landscape (0.32 ha) located in the Belgian Hautes Fagnes plateau. The primary objective was to evaluate the potential of multi-sensor UAV RS for characterizing soil CO_2 efflux and studying the importance of hotspots within peatland ecosystems.

The carbon emissions show large spatial and temporal variations during the monitoring period. The CO_2 fluxes were significantly higher at the summit (3.16 ± 3.25 μmol m□² s□¹) and shoulder positions (dry: 2.81 ± 3.22 μmol m□² s□¹; wet: 2.33 ± 2.36 μmol m□² s□¹) compared to the footslope (1.25 ± 1.00 μmol m□² s□¹) and backslope (1.11 ± 1.03 μmol m□² s□¹) positions (ANOVA, $p < 0.05$). Our findings reveal that UAV data can produce reliable high-resolution maps (resolution = 0.15 m) of soil respiration rates across heterogeneous landscapes, achieving an RMSE of 0.64 μmol m□² s□¹ and an R^2 of 0.74. These maps allowed us to pinpoint CO_2 efflux hotspots, whose locations and magnitudes varied over time. Despite occupying less than 10% of the landscape, these hot spots contributed disproportionately to the total CO_2 efflux, accounting for up to 40% during the hot summer and early autumn periods, highlighting their significant role in peatland carbon emissions.

Our study demonstrates that integrating UAV RS with field surveys improves the accuracy of peatland carbon efflux monitoring and assessments. This provides valuable insights into carbon dynamics and supports peatland conservation and climate change mitigation efforts.