Modelling Forest Floor Temperature Offsets from Terrestrial Laser Scanning

Andreas Hanzl[1], Karun Dayal[2], Katja Kowalski[1], Felix Wieland-Glasmann[1], Kim Calders[2], Cornelius Senf[1]

[1] Earth Observation for Ecosystem Management, School of Life Sciences, Technical University of Munich, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

[2] Q-ForestLab, Department of Environment, Ghent University, Campus Coupure - Block A, Coupure Links 653, 9000 Ghent, Belgium

Abstract: Forest microclimate strongly influences seedling survival and forest regeneration, particularly under increasing climate extremes. The degree to which forest temperatures deviate from open-land conditions depends directly on canopy cover, which regulates incoming solar radiation. As a result, forest canopies create fine-scale spatial variability in temperature that cannot be captured continuously across space using conventional, but labor-intensive, in-situ temperature loggers.

Here, we demonstrate that terrestrial laser scanning (TLS) provides a spatially explicit approach for mapping forest floor temperature offsets. We acquired high-resolution three-dimensional structural data using a Riegl VZ-400i across eight 1-ha plots in the National Parks of Berchtesgaden (Germany) and Bosland (Belgium), scanned on a regular 10 m grid. Forest floor temperatures were measured using TOMST TMS-4 loggers deployed on a 20 m grid. We linked TLS-derived structural information to forest floor temperature offsets, defined as the difference between temperatures recorded at nearby weather stations at a standardized height of 2 m and microclimate temperatures measured 15 cm above the forest floor.

XGBoost models based on structural vegetation metrics, including height percentiles and finely resolved canopy height models (50 cm resolution) within a 10 m buffer around each logger location, achieved high predictive accuracy (cross-validated $R^2 > 0.8$). These results highlight the potential of high-resolution TLS data to predict forest floor temperature offsets at spatial resolutions as fine as 1 m. By aggregating predictions to coarser grid sizes, we further demonstrate scaling behavior and quantify the information gained relative to coarser products, such as satellite-derived temperature data at 30 m resolution. Overall, this approach offers a promising pathway for local assessments of forest floor temperature patterns and their implications for forest dynamics, including regeneration under climate change and evolving forest management strategies.

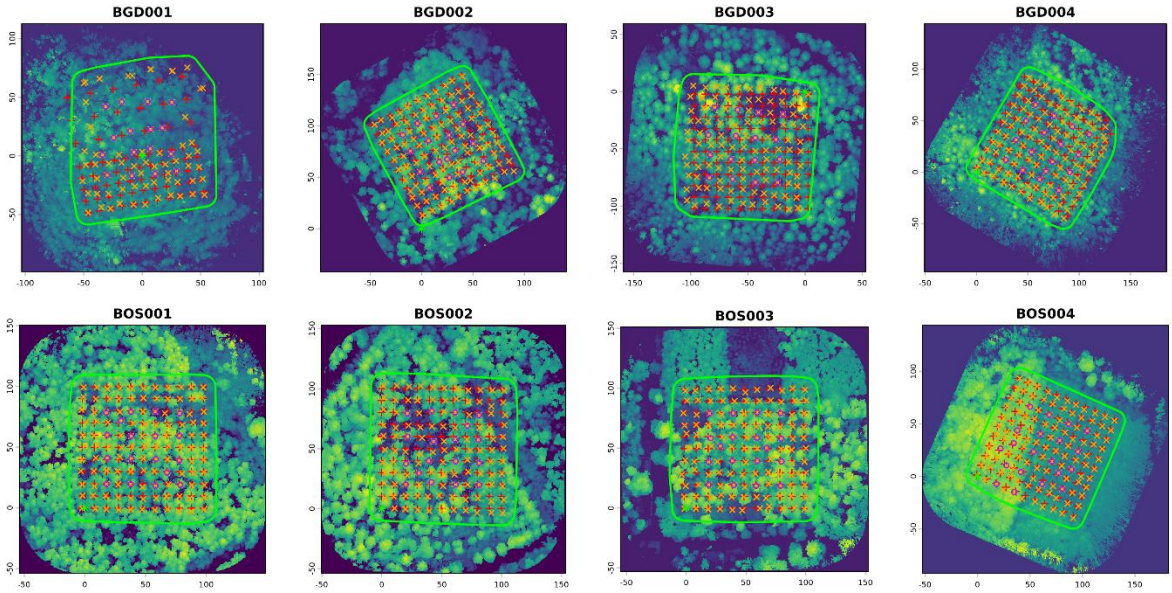

Figure 1: TLS-derived canopy height models at 50 cm resolution of the eight study sites with 121 scan positions each and the core study area outlined by the green margin.

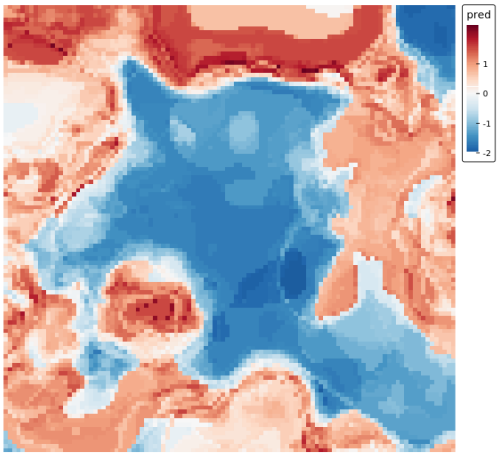

Figure 2: Prediction of forest floor temperature offsets at 1m resolution based on an XGBoost model using TLS-derived canopy metrics.