EGU22-10166
https://doi.org/10.5194/egusphere-egu22-10166
EGU General Assembly 2022

Mapping Wildfire Fuels, Behavior, and Hazard in a Managed Temperate Forest Using Airborne LiDAR and Sentinel-1 & -2

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In the light of climate change both number and duration of droughts and heat waves in Central Europe are projected to increase. Such developments will affect vegetative fuels and may alter the local fire regime. Wildfire is expected to expand into new, traditionally non-fire-prone regions such as the temperate zone. While having been a negligible threat until recently, more and larger fires can be anticipated in Central Europe.

Integrated fire hazard is a valuable metric for forest and fire management and may support safety planning efforts and decision-making. It combines flame length and burn probability which can be derived from fire spread simulations. These rely on multiple spatial variables related to topography, climate and fuels. Information on fuels is thereby most challenging to acquire as they vary significantly in space and time. Modeling surface and canopy fuel variables requires extensive field data. Both can strongly benefit from incorporating remote sensing data in their prediction.

We present a comprehensive assessment of wildfire fuels, behavior and hazard for a small managed temperate forest in north-western Germany. Dominant species present include Scots pine (Pinus sylvestris), European Beech (Fagus sylvatica) and red oak (Quercus rubra). Located in a densely populated region the study area is highly frequented for recreational purposes.

Field data was collected to describe surface (n = 215) and canopy (n = 30) fuel characteristics. A total of 119 variables was extracted from airborne LiDAR point clouds and Sentinel-1 and -2 imagery. These facilitate predictive modeling of spatially continuous fuel variables at 10 meter resolution. Three surface fuel types were classified using a Random Forest model combined with a Forward Feature Selection process. Canopy Cover, Canopy Height and Crown Base Height were directly derived from LiDAR data. Crown Bulk Density was modeled through Ridge regression. The classification model scored an OA of 0.971 (Kappa: 0.967) whereas the regression model performed notably weaker (RMSE = 0.054; R^2 = 0.59).

We simulated fire spread from random ignitions considering an array of environmental scenarios with varying wind speed, air temperature and fuel moisture content. Results show most elevated fire hazard for high wind speeds and low fuel moisture. Further, slope and surface fuel type are relevant factors. Fires burned fastest and most frequently on slopes in large homogeneous pine

stands. Therefore, preventative measures should be focused on these sites.