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Treeline spatial patterns for biodiversity monitoring detected by spectral and 3D information from UAV□based aerial imagery

Erik Carrieri[1], Fabio Meloni[1], Carlo Urbinati[2], Emanuele Lingua[3], Raffaella Marzano[1], and Donato Morresi[1]

[1]University of Turin, DISAFA, Grugliasco, Italy (erik.carrieri@unito.it)
[2]Universitá politecnica delle Marche, Dept. of Crop, Food and Environmental Sciences, Ancona, Italy (c.urbinati@staff.univpm.it)
[3]University of Padova, TESAF, Legnaro, Italy (emanuele.lingua@unipd.it)

Treeline ecotones spatial patterns and dynamics are influenced by factors acting at regional, landscape, and local scales. It is widely accepted that treelines change in complex ways depending on their diverse structural features and environmental conditions.
The high variability of environmental conditions and ecological drivers hampers the creation of a general pattern from case studies. A multi-scale approach applied at numerous locations is needed to discriminate between natural and anthropogenic factors that are driving treeline dynamics. Remote sensing techniques are today fundamental tools for a comprehensive assessment of the spatial heterogeneity of treeline patterns and their changes over space and time. Continuous improvements in remote sensing platforms, sensors, and methodologies have considerably increased the quality and reliability of spatial information, such as forest maps, which are essential for monitoring ecotonal dynamics.
In this study, we aimed to comprehensively map individual tree canopies at the treeline ecotone in 10 different sites distributed across the Italian Alps by integrating field and UAV-based data. We first mapped the position of the forestline using the 2018 pan-European Tree Cover Density layer provided by the Copernicus Land Monitoring service. In particular, we considered the pixel line where the tree canopy cover was less than 10% as the forestline. Field data consisted of position, height, and species of 100 trees taller than 50 cm scattered over a 9-hectare area. Each site was also flown over by a multirotor drone to produce an RGB orthomosaic, a digital surface model, and a canopy height model. A total of 1016 individual canopies of different coniferous species were manually classified on the orthomosaics with the aid of semi-automatic annotation software. These data were used to train a deep learning model based on the Mask R-CNN algorithm for object detection and segmentation. The classification masks were lastly combined with a canopy height model providing 3-dimensional information allowing to measure tree height. Preliminary results evidenced that remotely sensed data collected with low-cost equipment such as commercial drones with RGB cameras, coupled with the proposed canopy detection method can be used to produce highly accurate and reliable maps of treeline ecotones. These maps will serve as a starting point to study and monitor the spatio-temporal dynamics of treeline ecotones at the local scale and how they affect biodiversity in high-altitude environments.