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Estimating canopy and stand structure in hybrid poplar plantations from multispectral UAV imagery

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Accurate estimates of canopy cover (CC),tree and stand structure are required to manage poplar plantations effectively. However, traditional measurements are limited by the cost and time-consuming nature of field methods, which inherently have limited the large scale adoption of *in situ* approaches. Satellite remote sensing has the advantage of broader geographical coverage, but its spatial and temporal resolution is often not suited for tree- to stand-scale applications as required in precision plantation forestry. Recently, unmanned aerial vehicles (UAVs) have become very popular in forestry. In this contribution, we tested the use of UAVs for retrieving plot-level canopy and stand attributes in hybrid poplar plantations, which were sampled in Northern Italy. A multispectral camera sensor was equipped to a multi-rotor UAV, and was used to acquire orthorectified images of 50 poplar plantations, each 0.25 ha in size, with varying age and plant density. In addition, field optical measurements of canopy structure made by digital cover photography and mensurational attributes derived from tree inventory were also performed and used as ground truth data.

The very high resolution of UAV imagery (<10 cm) allowed to efficiently perform a Simple Linear Iterative Clustering (SLIC) algorithm for superpixels generation, which was used to delineate individual poplar crowns automatically. The segmented images were then processed using Gray-Level Co-occurrence Matrices (GLCM) to calculate specific texture attributes, which were benchmarked against ground truth measurements.

Results indicated that multispectral UAVs can estimate canopy and stand structure attributes in poplar plantations reliably and accurately. Based on model performance indicators, the best model is that relating stand features to image dissimilarity. Its RMSE is in line with the standard deviations of the observed values, meaning that the error associated with the prediction is in line with the uncertainty of the calibration dataset.

The basal area, the volume of the trunk and the crown volume were the most correlated attributes with image dissimilarity valued from GLCM.By contrast, crown cover (CC) and leaf area index (LAI) were the model's attributes that could fit the worse following the clustering effect of plants' age and the leverage occurring in some stands that results in ground truth data overestimation.

We concluded that use of UAVs can be considered an efficient tool in poplar plantation forestry. Considering the multi-scale nature of poplar plantation interventions, UAVs are particularly relevant as they can bridge between field and satellite measurements. Regarding the latter, the high resolution of UAV imagery also allows calibrating metrics from coarser scale satellite products, avoiding or reducing the need for field calibration efforts.