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| **Estimating canopy and stand structure in hybrid poplar plantations combining digital terrestrial photography and multispectral UAV imagery.** |
| **Introduction/Aim:**  In today’s context, the adoption of precision forestry tools for managing poplar plantations is highly desirable (Corona et al., 2022; Fardusi et al., 2017). These new instruments offer the potential to update and develop advanced monitoring systems, providing precise estimation of various poplar variables at both stand and tree levels (Dash et al., 2016; Fardusi et al., 2017; Puletti et al., 2019). In fact, timely and accurate monitoring of poplar plantations is essential (Cantamessa et al., 2022; Meroni et al., 2004; Pu et al., 2021). Among the various poplar plantation variables, precise estimates of canopy characteristics such as canopy cover (CC), Leaf Area Index (LAI), and Crown Volume (Vcr) are of fundamental importance for effective poplar plantation management. These variables have a direct impact on the growth rate and the occurrence of poplar stress (Gago et al., 2015; Li et al., 2023).  **Methods:**  In this study, we examined the use of multispectral photogrammetric data collected via UAVs with a Micasense RedEdge camera for the retrieval of canopy and stand attributes within hybrid poplar plantations, developing a methodology that integrates terrestrial digital photos to predict the above-mentioned variables.  Terrestrial digital photography was used at the plot level to acquire digital cover photography (DCP) images (Macfarlane et al., 2007) under overcast sky conditions along a grid of 16 sampling points using a digital single-lens reflex camera (Nikon D90) fitted with an AF Nikkor 50mm 1:1.8 D fixed lens, which yields a field of view of about 30°. From DCP, we calculated the canopy variables: CC, LAI, and Vcr. The multispectral UAV orthomosaic was instead used to segment the single crown of the poplar plantation using the RedEdge band and a Simple Linear Iterative Clustering (SLIC) algorithm. Based on the segmented tree crowns, the Grey Level Co-occurrence Matrix (GLCM) was calculated for each crown based on different spectral bands and used to predict the canopy variables at the single tree level.  **Results:**  The accuracy was calculated based on an independent dataset, and the results showed a significant correlation between predicted and measured values of the considered poplar plantation variables (i.e., Vcr, CC, and LAI) with R2 consistently higher or equal to 0.86 (R2 val.) for all the tested models. The most accurate predictions for LAI and CC were achieved using GLCM variance calculated on the RedEdge band, while GLCM entropy calculated on the base of the NIR band performed for Vcr. The MAE and the RMSE are generally consistent with the standard deviations of the observed values for all the variables (Vcr = 131.2; CC = 0.23; LAI = 0.64).  **Conclusion:**  This research underscores the importance of GLCM texture metrics derived from multispectral UAV orthomosaic as significant explanatory variables for accurately predicting poplar plantation canopy characteristics. The results of this study suggest that the proposed approach provides a dependable and efficient alternative to traditional measurement techniques, necessitating only a limited number of field plot acquisitions. Additionally, the use of DPC also reduces the time required for plot acquisition compared to extensive traditional field campaigns. |

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