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Estimation of total biomass using low-density airborne laser scanning data in Aleppo pine forested areas

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Forest ecosystems and their associated understory acts as important carbon sinks, providing habitats for wildlife and promoting economic and social development. The estimation of tree and shrub biomass in the Mediterranean basin also contributes to better understand fire behaviour, which constitutes one of the most relevant disturbances and a source of greenhouse gas emissions to the atmosphere. Numerous studies have demonstrated the effectiveness of remote sensing techniques to estimate biomass, from optical sensors to Synthetic–aperture radar (SAR) or Airborne Laser Scanning (ALS), given the capability of these latter ones to provide 3-D information of vegetation structure. However, little research has focused on the estimation of total biomass including shrub fraction. The lack of knowledge of shrub vegetation associated with the necessary destructive sampling to generate forest structure equations might have been one of the drawbacks to include those species for biomass and carbon account. In this sense, the development of new allometric equations for shrub species defined to estimate biomass from simple field measurements and the generalization of ALS data have opened new opportunities for total biomass estimation.

The availability of wall-to-wall ALS data of low spatial resolution (0.5 points/m2) provided by the Spanish National Plan for Aerial Orthophotography (PNOA), as well as the existence of new allometric shrub equations, determined the main objective of this research. Accordingly, this study focuses on the estimation of total biomass, including tree biomass and shrub biomass fraction, in Aleppo pine (Pinus halepensis Miller) forest stands in Aragon region (Spain). Two variable selection methods and two regression methods were compared in order to relate the total biomass, estimated in 83 field plots, to several independent variables derived from ALS point cloud. The Spearman's rank correlation and "all subset selection" were analyzed for variable selection, considering a maximum number of three predictor metrics. A multivariate linear regression (MLR) and two support vector machine (SVM) models, with radial and linear kernels, were compared. A calibration sample, integrated by 62 plots, and a validation sample, composed by 21 plots, was used for total biomass modeling. MLR presented the most accurate results including three ALS metrics: (i) the 25th percentile of the return heights; (ii) the variance; and (iii) the percentage of first returns above mean (root mean square error after validation of 15.14 tons/ha). The implementation of the model in a GIS environment allowed total biomass mapping. This study confirms the usefulness of low-density ALS data to accurately estimate total biomass including shrub fraction to better assess the availability of biomass and carbon content in a Mediterranean Pinus halepensis Miller forest.