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Estimation of biomass and volume of shrub vegetation using LiDAR and spectral data in a Mediterranean environment

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ABSTRACT

Several studies have addressed the biomass and volume of trees using Airborne Light Detection and Ranging (LiDAR) data. However, little research has been conducted into shrub vegetation, which covers a high percentage of Mediterranean forest. We used LiDAR data and an airborne image to estimate biomass and volume of shrub vegetation. Field data were collected in 29 square plots of 100 m^2. In each plot, the percentage of the surface covered was measured in the field. Shrub vegetation inside 3 stands for each plot was clear cut to calculate the biomass and volume of the 29 plots. To find the best fit between LiDAR-spectral data and field measurements, stepwise regressions were performed using previously selected variables. The highest accuracy was found when variables derived from LiDAR data and the airborne image were combined (R^2 values of 0.78 and 0.84 for biomass and volume, respectively). Biomass and volume were predicted using variables from height metrics of LiDAR data (median and standard deviation); density metrics (percentage of points whose height was between 0.50 m and 0.75 m, 0.75 m–1 m, and higher than 1 m); and spectral data (standard deviation of green band, mean of the vegetation index NDVI). These results revealed the potential of LiDAR and spectral data to characterize shrub structure and make it possible to estimate and map the biomass and volume of this vegetation.

1. Introduction

A high percentage of Mediterranean forest consists of dense, low shrub. The difficulty involved in shrub management and the lack of information about shrub behavior means that these areas are often left out of spatial planning projects. Nevertheless, these shrub ecosystems are important for the environment and landscape because they prevent soil erosion and desertification [1]; contribute to managing the wildlife habitat [2]; contribute to creating fuel-type maps for better accuracy in fire behavior modeling [3]; represent important CO_2 sinks; and help refill aquifers [4,5]. For management of forest areas, biomass is a key variable as it allows the function and structure of the ecosystem across the landscape to be evaluated [6–8]; and it is a potential source of renewable energy [9,10].

LiDAR has been used successfully in the last decade in forest applications [11–13]. In applications related to forest inventories, two approaches can be followed [14]: (i) estimation of the dasometric variables using regressions between

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field data and statistics derived from LiDAR data in a plot or stand [15–18]; and (ii) calculation of the dendrometric variables needed to delineate the crown of a tree [10,19,20].

Little research has been conducted into shrub areas because of the inherent difficulty: this vegetation is low and occupies a continuous surface in which individual elements cannot be defined. Therefore, only the plot-stand approach can be applied. Moreover, their low height requires high accuracy levels in methodology and LiDAR data characteristics. Sometimes, buffers are used when vegetation heights measured in the field are compared to those calculated from LiDAR data to find the maximum correlations between both data [21]. A threshold is usually applied to LiDAR data in forestry applications to eliminate points close to the ground [22–24]. This value represents the maximum elevation to consider in shrub studies.

Most studies of shrub vegetation using LiDAR data have been based on height estimation and presence/absence of shrub vegetation [3,21]. As with trees, shrub height is underestimated using LiDAR data [25–27]. In relative terms, this underestimation is more important for shrub vegetation as it is lower in height [28–30]. However, less attention has been paid to biomass and volume estimation, which are key variables for forestry applications. One of the reasons for this is the difficulty of measuring the variables to be correlated with LiDAR data in the field. Without this data, the parameters extracted from LiDAR data cannot be correlated. Another reason is the lack of knowledge of this type of vegetation, unlike trees, where allometric equations are defined to estimate dendrometric variables from simple measurements. In studies based on mapping the presence or absence of shrub vegetation, good results were obtained when only LiDAR data was used [31]. In addition, the detection of this vegetation was improved when LiDAR data and spectral information were combined [2,32,33]. Other studies successfully used this data combination to produce a classified vegetation map [26,34]. In forest applications, it was reported that when these data were all used together the prediction models improved significantly [35–38]. Therefore, it is a specific issue to analyze whether this combination of data can improve the prediction models for biomass and volume of shrub vegetation.

The aim of this paper is to study the possibility of estimating key variables for biomass and volume of shrub areas, which cover a high percentage of Mediterranean forest, by analyzing the combination of data which produces the highest accuracy in the predicted models. The regression equations can be applied to map the volume and biomass of the study area [39,40]. The results presented here illustrate the feasibility of estimating these variables.

2. Materials and methods

2.1. *Study area*

The 10 km^2 study area is located in Chiva (Valencia, Spain), defined by a rectangle whose UTM coordinates $X_{maximum}$, $Y_{maximum}$, $X_{minimum}$, and $Y_{minimum}$, are 689,800 m, 4,376,028 m, 683,800 m, and 4,373,000 m, respectively (Fig. 1). The area is located in zone 30 N in the European Datum 1950 reference system. It is a mountainous area with a predominance of *Quercus coccifera* (Fig. 2), although other species can be found such as *Rosmarinus officinalis, Ulex parviflorus, Cistus albidus L.* and *Erica multiflora L.* These species are the most abundant in Mediterranean forests. The average occupation fraction of

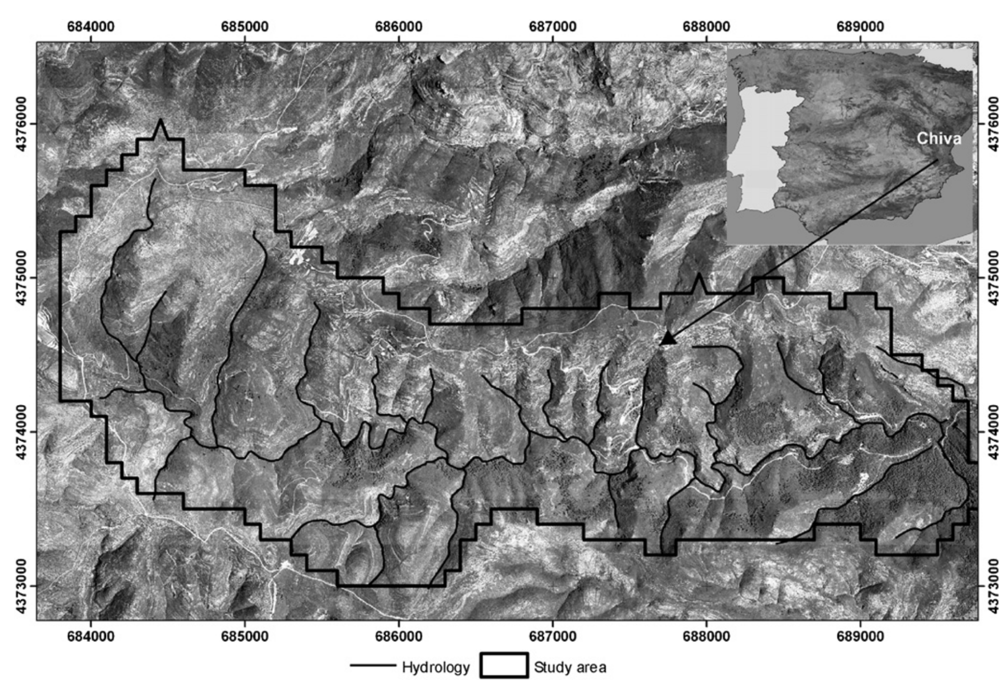

Fig. 1 – Location of study area in Chiva (Spain). The black polygon represents area surveyed for LiDAR.