Analysis of factors for predicting shrub biomass in small stands using ALS data

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Abstract

The presence of shrub biomass is very relevant in Mediterranean ecosystems. Our objective was to estimate shrub biomass in small stands using discrete airborne laser scanner (ALS) data, and to analyze the factors that affect these estimations. A total of 83 stands with radius 0.5 m located in Chiva (Spain) were cleared out and weighted. Linear models were obtained relating biomass values from field data to maximum height from ALS data within each stand. The factors analyzed were: type of shrub vegetation, error associated to digital terrain model (DTM), and density of ALS data. A low R^2 (0.31) was obtained considering all plots without restrictions. A relevant increase of prediction (R^2=0.63) was observed for stands with *Quercus coccifera*, low error associated to DTM (RMSE<0.20 m), and ALS point density higher than 8 points/m^2. The results show the feasibility of predicting shrub biomass in small stands under certain conditions.

Extended Abstract

The objective of this study was to estimate shrub biomass in small stands (radius = 0.5 m) by means of ALS data, and to analyze the relevance of the following factors in the accuracy of the models obtained: vegetation species, error associated to DTM, and density of ALS data.

Materials and Methods

The study area is located in Chiva (Spain) and covers about 10 km^2. This is a mountainous meso-Mediterranean bioclimatic area, predominantly covered by shrub vegetation, being the most abundant species *Quercus coccifera* (Fig. 1a), having a height variation between 442 and 1,000 m, and an average slope of 45%.

The ALS data was acquired in December 2007, using an Optech ALTM 2050 system. The technical parameters were: flight height – 700 m above ground; pulse frequency – 50 kHz; scan frequency – 47 Hz; scan angle – ±18º; speed flight – 70 m/s; swath width – 400 m; number of strips– 10; total points obtained for the test area – 78,919,301; nominal pulse density – 4 points/m^2; Number of echoes - 2. However, given that 10 overlapping flight lines were registered, some areas had higher point density, being the average point density in the study area 8 points/m^2.

ALS data were normalized into heights above ground to calculate explanatory variables. For this, a DTM was computed using an algorithm based on the iteratively selection of minimum elevations in decreasing analysis windows and height thresholds definition to remove vegetation points (Estornell et al., 2011a). A set of 1397 checkpoints randomly located across the study area were measured with a RTK-GPS system. The root mean square error (RMSE) was 0.19 m.

The field biomass was measured in 83 circular stands of radius 0.5 m randomly distributed across the study area. The vegetation inside them was clear cut. In each clear cutting we counted the number of shrub plants inside the stand, identified the species, and measured the weight for each plant. After applying a drying process for some individuals of each species, the dry weight of each clear cutting shrub was also measured. The stand biomass was obtained by adding the weight of each plant in each stand. The average and standard deviation of the shrub biomass were 4.17 kg and 1.98 kg, respectively.

The *maximum height* derived from ALS data within each stand was used as the only explanatory variable in the regression model. Previously, the bare-earth surface elevation was subtracted from each ALS point based on the DTM value. Then, the influence on the accuracy of biomass estimations of the factors vegetation type, error associated to the DTM, and density of ALS data were analyzed. In order to analyze the vegetation factor in the prediction models, the stands having the most abundant species *Quercus coccifera* were selected. The rest of stands showed either a reduced presence of this vegetation or a mixture of species. For the analysis of the density factor, the number of ALS points in each stand was calculated, and they were classified into two classes: density > 8 points/m^2, and density < 8 points/m^2. Finally, the differences between the coordinate z in each stand center measured with GPS-RTK and the coordinate z from the DTM were calculated to study the influence of the error associated to DTM. Then, the stands were grouped into two classes: those with differences lower than 0.20 m in absolute value, and those with differences greater than 0.20 m, also in absolute value. This threshold value was fixed since it was the RMSE of the DTM computed. All possible combinations considering two factors were analyzed (Table 1). Linear regression models to predict the shrub biomass of the stands were obtained and compared using R^2 values. Finally, shrub biomass using the optimal factors, i.e. stands with *Quercus coccifera*, density > 8 points/m^2, and DTM error lower than 0.20 m, was predicted.

Results and Discussion

A low R^2 value (0.31) was obtained when all stands were selected for estimating shrub biomass (Table 1). This result can be explained considering that within some of the stands of radius 0.5 m, there were very few ALS points. In these cases, the likelihood that these points belonged to the canopy was low. In addition, the rough terrain with high slopes that characterizes the area requires high accuracy in the computation of the DTM. In stands with high DTM error (RMSE > 0.20 m) a relevant relative underestimation or overestimation of the maximum canopy height derived from ALS data can occurs, especially with this type of vegetation whose average height was 1.27 m (Estornell et al., 2011b). As observed in table 1, low values of R^2 were obtained for stands with density of data lower than 8 points/m^2 and/or error associated to DTM greater than 0.2 m.

However, important increases of R^2 were obtained when the stands were grouped considering factors such as, vegetation type *Quercus Coccifera* and error DTM lower than 0.20 (R^2 = 0.49); *Quercus Coccifera* and density of data greater than 8 points/m^2 (R^2 = 0.55); and DTM error lower than 0.20 m and density data greater than 8 points/m2 (R^2 = 0.57). The highest R^2 value was found when the shrub biomass was estimated in stands where the three most restrictive conditions were considered (R^2 0.63) (Fig. 1b). These results reveal the importance of the factors DTM accuracy and density of data to predict shrub biomass in rough terrains. The potential of ALS data for predicting biomass of *Quercus Coccifera* in Mediterranean ecosystems under certain conditions and in small stands was also shown.

References

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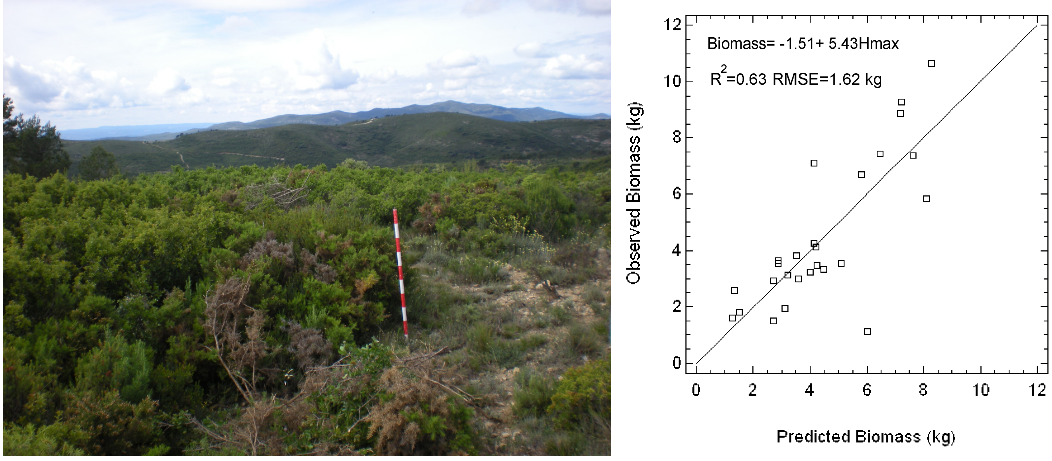

(a) (b)

Fig. 1 (a) Detail of the study area with dense presence of *Quercus coccifera;* (b) Predicted vs. observed biomass values for small stands under certain restrictive conditions.

Table 1 Shrub biomass estimation in a stand of 0.5 m combining the factors *Quercus Cocciferra vegetation, DTM error*, and LiDAR *density.*

Cases	n	Models	R^2	RMSE (kg)
All stands	83	*Biomass* = $1.50 + 3.02 \cdot H_{max}$	0.31	1.68
Quercus Coccifera and density <8 points/m^2	15	*Biomass* = $4.04 + 0.69 \cdot H_{max}$	0.01	2.06
Quercus Coccifera and density >8 points/m^2	32	*Biomass* = $-0.82 + 4.91 \cdot H_{max}$	0.55	1.68
Quercus Coccifera and DTM error > 0.2 m	17	*Biomass* = $3.91 + 0.69 \cdot H_{max}$	0.01	2.04
Quercus Coccifera and DTM error < 0.2 m	30	*Biomass* =$-0.19 + 4.37 \cdot H_{max}$	0.49	1.80
density <8 points/m^2 and DTM error > 0.2 m	8	*Biomass* = $3.39 - 0.37 \cdot H_{max}$	0.00	1.51
density <8 points/m^2 and DTM error < 0.2 m	39	*Biomass* = $-0.70 + 4.75 \cdot H_{max}$	0.57	1.55
density >8 points/m^2 and DTM error > 0.2 m	23	*Biomass* = $2.70 + 2.64 \cdot H_{max}$	0.24	1.70
density >8 points/m^2 and DTM error < 0.2 m	13	*Biomass* = $2.47 + 1.51 \cdot H_{max}$	0.17	1.29
Quercus Coccifera, density > 8 points/m^2, and DTM error < 0.2 m	26	*Biomass* =$-1.51 + 5.43 \cdot H_{max}$	0.63	1.62