



## Biomass estimation with high resolution satellite images: A case study of *Quercus rotundifolia*



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### ABSTRACT

Forest biomass has had a growing importance in the world economy as a global strategic reserve, due to applications in bioenergy, bioproduct development and issues related to reducing greenhouse gas emissions. Current techniques used for forest inventory are usually time consuming and expensive. Thus, there is an urgent need to develop reliable, low cost methods that can be used for forest biomass estimation and monitoring. This study uses new techniques to process high spatial resolution satellite images (0.70 m) in order to assess and monitor forest biomass. Multi-resolution segmentation method and object oriented classification are used to obtain the area of tree canopy horizontal projection for *Quercus rotundifolia*. Forest inventory allows for calculation of tree and canopy horizontal projection and biomass, the latter with allometric functions. The two data sets are used to develop linear functions to assess above ground biomass, with crown horizontal projection as an independent variable. The functions for the cumulative values, both for inventory and satellite data, for a prediction error equal or smaller than the Portuguese national forest inventory (7%), correspond to stand areas of 0.5 ha, which include most of the *Q. rotundifolia* stands.

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## 1. Introduction

Holm oak (*Quercus rotundifolia* Lam.) is a forest species native to the Mediterranean basin, distributed throughout the region, from Portugal to Syria (Forey, 1996; Valdés et al., 1987). This species is one of the most important forest trees in the dry summer areas of the Iberian Peninsula. In Portugal, according to the national forest inventory, *Q. rotundifolia* stands account for approximately 413,000 ha, corresponding to 13.7% of the Portuguese and 83% of the Alentejo forest areas (IFN5, 2010). *Q. rotundifolia* usually occurs in low density stands in a silvopastoral system, called *montado*, with open heterogeneous canopies, where the main product is fruit, associated with extensive grazing.

According to the national forest inventory (IFN5, 2010), in Alentejo, the density of this forest system ranges from 30 to 200 trees per hectare, with 95% of the area with less than 80 trees

per hectare; ground cover is in the 10–30% class in a quarter of the area and the remaining areas are in the over 30% class; and biomass has a value of 23.2 t/ha with a 7.2% error for pure stands.

### 1.1. Above ground biomass estimation

There has been increased interest in biomass for bioenergy and bioproducts, as it can meet the increasing needs for raw materials and fuel, with less negative impacts on the environment (Volk et al., 2006). It is necessary to have a highly accurate estimate of forest biomass in order to evaluate carbon stock and carbon changes, for the Kyoto Protocol (Muukkonen and Heiskanen, 2007), but using the direct or indirect methods is time consuming and expensive (Watzlawick et al., 2006).

The direct method is the most expensive and labour intensive, as trees have to be cut and the different components (wood, bark and crown) separated, weighed and sampled, in order to determine the dry weight. These data, usually from a small sample of trees, are used to fit functions that estimate biomass per tree, as a function of easy to measure dendrometric parameters. Most functions

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