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Estimation of positions and heights from UAV-sensed imagery in tree plantations in agrosilvopastoral systems

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ABSTRACT

Plantations of typical Mediterranean tree species, such as cork oak (*Quercus suber* L.), holm oak (*Quercus ilex* L.), and umbrella pine (*Pinus pinea* L.), are important for the restoration of forest ecosystems in the region. While traditional forest inventories can provide early problem detection in these plantations, the cost and labour of the required fieldwork may exceed its potential benefits. Unmanned aerial vehicles (UAVs) provide a cheap and practical alternative to traditional inventories and individual tree measurement. We present a method to estimate heights and positions of individual trees, from remotely sensed imagery, obtained using a low-flying UAV with an integrated RGB sensor. In the summer of 2015, a 5 ha stand at the University of Évora was photographed with a low-flying (40 m) hexacopter. A 3D point cloud and orthophoto were created from the images. The point cloud was used to identify local maxima as candidates for tree positions and height estimates. Results showed that the height measured with the UAV was reliable on pines, whereas the reliability for oaks was dependent on the size of the trees: smaller trees were especially problematic as they tended to have an irregular crown shape, resulting in larger errors. However, the error showed a strong trend, and adequate models could be produced to improve the estimates.

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KEYWORDS

Tree height; local maxima; unmanned aerial vehicle; tree positions

1. Introduction

The cork oak (*Quercus suber* L.) woodlands are highly biodiverse Mediterranean ecosystems; one of the most important silvicultural features of this species is cork extraction, which is removed periodically without felling the trees (every 9–12 years). For countries like Spain and Portugal, cork is an important economic factor, together with holm oak (*Quercus ilex* L.) and umbrella pine (*Pinus pinea* L.). Other important species, such as blue gum (*Eucalyptus globulus* L.), are of great significance, not only from a commercial point of view but also for their high capacity for carbon sequestration and extraction of water and nutrients. Consequently, systematical and accurate management can strongly influence their environmental impacts. These woodlands can be described as ‘complex forest management systems,’ which can be characterized by a limited capacity to respond to

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