Crown area allometries for surveying blossoming wild cherry with unmanned aerial system (UAS)

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Summary

Inventory of blossoming wild cherry is achieved thanks to a small Unmanned Aerial Systems which delivered very high resolution map of the tree blooming crowns. Tree circumference at breast height is subsequently determined on the basis of developed allometric relation that take advantages of crown area and tree height, both of them measured remotely from the aerial images.

High temporal resolution and flexibility of lightweight UAS enable forest scientist to fit acquisition with ecological phenomena as blooming event. Both Digital elevation model and orthophotomosaic are generated with Structure from Motion/Photogrammetric workflow, although orientation of leaf-off canopy images block is challenging.

Introduction & Motivation

Mature precious broadleaved trees as wild cherry (***Prunus avium***) have always been coveted because of theirs valuable wood. Quantifying and locating their presence in a forest is nevertheless challenging, as these species are usually clustered in small group through deciduous forest. The goal of this study is to develop new allometric equation for estimating and locating wild cherry resources from small UAS imagery.

Material & Method

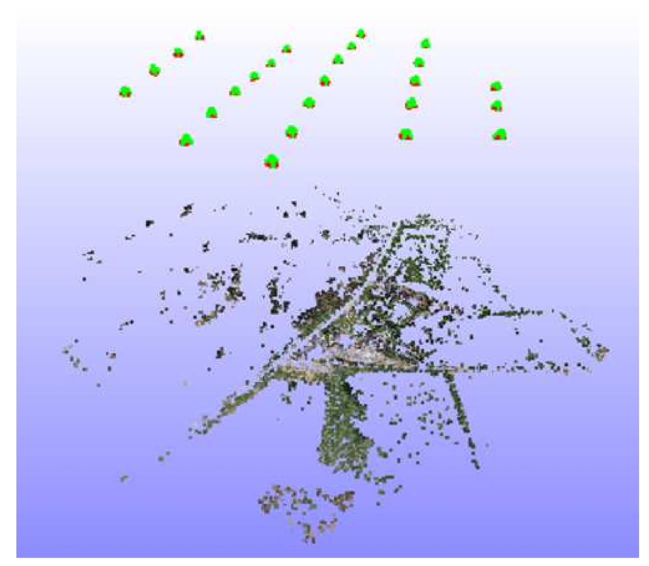
Study area is a 130 ha broadleaved forest located in Grand-Leez, Belgium. Stands are mixed, uneven-aged and the main species is oak (*Quercus robur* and *Quercus petraea*). UAS survey has been carried out during flowering event, at the earliest stage of vegetation growth.

Photogrammetric workflow: thanks to the UAS Gatewing X100 (http://www.gatewing.com), 540 aerial images covering the entire study area were collected in one single flight. Digital Surface Model and orthophotomosaic (DSM) are generated by means of Computer Vision/photogrammetric softwares (Agisoft Photoscan and MicMac [Pierrot-Deseilligny et Paparoditis, 2006]). Combined with a Digital Terrain Model (DTM), it produces a canopy height model [Dandois et Ellis, 2010, 2013].

Setting up of the small UAS. The Gatewing X100 is a fixed-wing of 2 kg flying with an electric motor. Its flight duration of 40 minutes enable to cover areas of more than 100 ha with high overlap (80%) at 250 m above ground level.

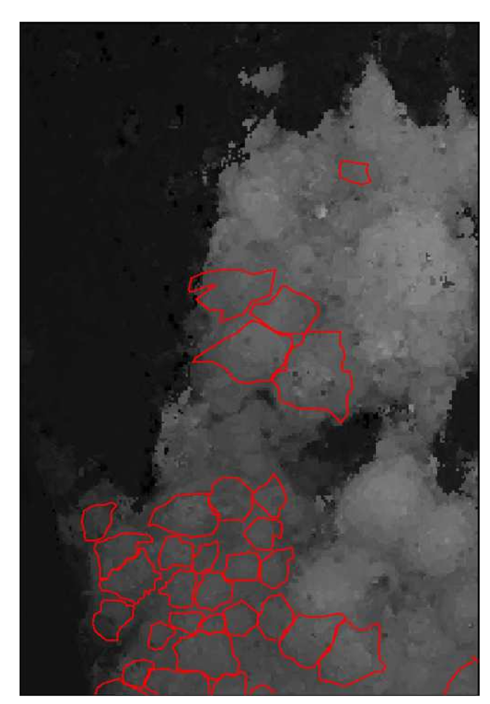
Allometric statistic model: Tree crown have been manually delineated on the orthophotomosaic and theirs girth at breast height have been measured on the field. In addition, the canopy height model provide area-based metrics computed for each wild cherry crown. Statistical weighted least square regression has been performed in order to predict circumference at breast height (exploratory variable) thanks to crown size and height percentiles (explanatory variables). Weighted least square regression has been used in order to take into account the heteroscadasticity of the residuals.

One of the 540 raw low-oblique images of blossoming wild cherry The ground sample distance is 8 cm. Sensor is a Ricoh GRIV (10 Mpixels, 6 mm fixed focal length).



Sparse 3D model and external orientation of camera. Success of image block orientation (aerotriangulation) required tie points which are scarce in leaf-off canopy. Image of a second flight have been utilized for enhancing redundancy (image overlap).

Dense 3D model (left) and orthophotomosaic (right). Image matching is hindered by numerous ommission and multi-layered structure of leave-off canopy.



Tree Crown manual delineation (left) and Height metrics computation (right).

Results

The explanatory variables selected by the stepwise regression procedure are the maximum height and the crown circumference. The equation was adjusted by weighted least square regression and has the following form:

$$CBH = \alpha + \beta * CC + \gamma * H_{p100}$$

$$\alpha = -68.771, \beta = 3.588, \gamma = 4.995, n = 194, r^2 = 70.02\%, RMSE = 25.1cm$$

with CBH is the circumference at breast height (i.e. 130 cm) [cm];
CC is the circumference of delineated crowns [m];
H_{p100} is the maximum height [m];

Discussions & Perspectives

Spatial and temporal resolution of UAS imagery shows plenty of opportunities [Anderson et Gaston, 2013] in the field of precision forestry. Localization and resource quantification of specific specie tree as wild cherry is achievable with lightweight UAS, provided that UAS surveys occur in synchronization with flowering event. Dense images matching for 3D reconstruction and canopy height measurements is hinder in leaf-off environment by numerous occlusions, multi-layered object, poor texture and very few characteristics objects [Baltsavias *et al.*, 2008; White *et al.*, 2013]. These issues could be bypassed by adapting consequently the aerial survey strategy: first flights should happens as late as possible, e.g. at the end of the tree blossoming when others trees start to have leaves. Moreover, additional flight occurring later in the growing period could also provide a sound canopy height model, as leaf-on canopy is much more appropriate for dense image matching.
Allometric relation between stem girth and the combination of crown size and tree height metrics explains 70 % of the variability of circumference at breast height. Although these results can seems weak at first sight in comparison with other studies in which model fit reach r^2 of 78% (Massada *et al.* [2006], biomass model), 85% in the study of Kuyah *et al.* [2012] (biomass model) and even 90.1% (Wang *et al.* [2007], stem volume model), this is very satisfying in the context of uneven-aged mixed deciduous forest.

Figure 1: Comparison of QuickBird and terrestrial images from the study of Wang *et al.* [2007] (left) and uneven-aged stands of Grand-Leez (right).

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