Mapping the height of heterogeneous vegetation from UAV-borne visible images and DSM

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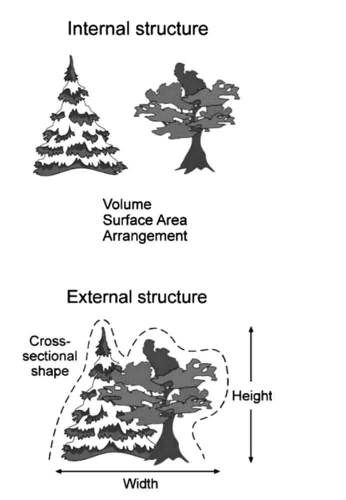
Context and objectives

Characterizing vegetation structure is essential for studying light distribution and air flow regime within agroforestry plots. Canopy heights and foliage density notably stand as key variables and should be described at both the internal and at the landscape scale.

The recent development of unmanned aerial vehicles (UAVs) and the miniaturization of devices for the acquisition of georeferenced images have open new possibilities for remote sensing applications that we intend to test here.

Vegetation internal and external or « landscape » structures – from Brandle et al. (2004)



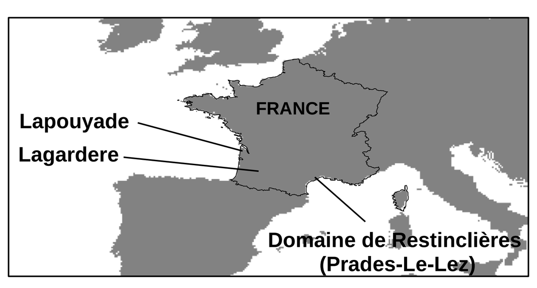
A generic methodology is proposed for describing vegetation structure of agroforestry plots using very high resolution stereoscopic visible and near-infrared images acquired through UAV flights.

Material

Three agroforestry vineyards were selected in Southern France in order to sample diverse contexts of vegetation structure.

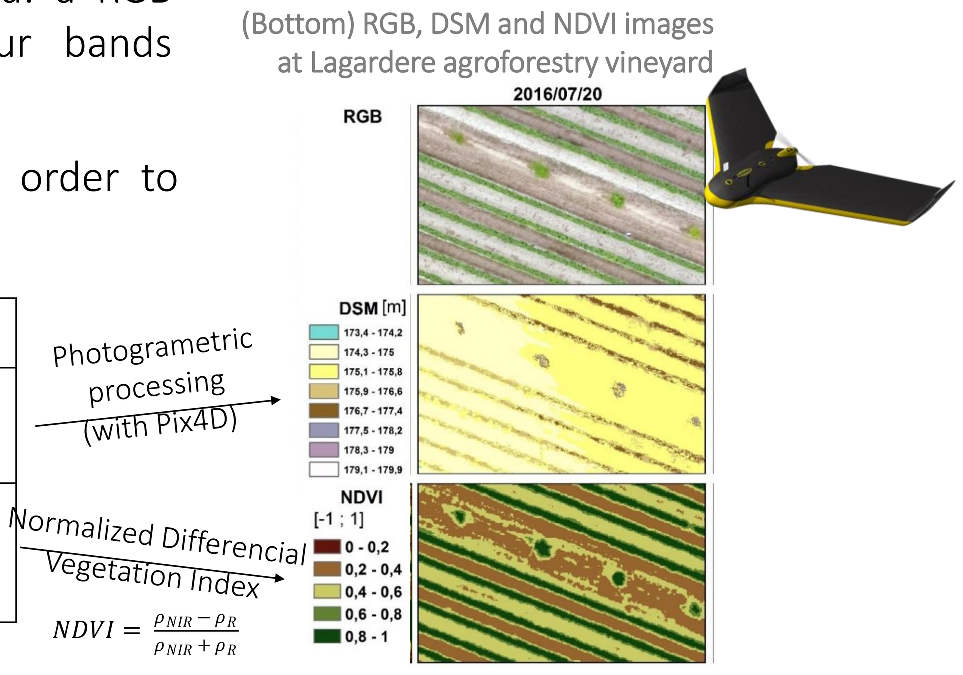
At each site, flights were performed in July and August 2016 using a polypropylene flying wing – eBee® from senseFly. Two sensors were successively used: a RGB (Red-Green-Blue) digital camera and a four bands multispectral sensor.

Flight trajectories and altitudes were set in order to generate at least 5 overlapping images.



(Top) Location of study sites.

(Bottom) RGB, DSM and NDVI images at Lagardere agroforestry vineyard



Device	Spectral bands center (w: width)	XY resolution of ortho-mosaïcs
RGB sensor DSC-WX220 (SONY)	$Blue_{RGB}$: 450 nm (w = 85 nm) $Green_{RGB}$: 520 nm (w = 125 nm) Red_{RGB}: 660 nm (w=75 nm)	5 cm
Multispectral sensor multiSPEC 4C (Airinov)	$Green_{MS}$: 550 nm (50 nm) Red_{MS}: 660 nm (w = 50 nm) $Red\text{-}Edge_{MS}$: 735 nm (w = 20 nm) NIR_{MS}: 790 nm (w = 60 nm)	10 cm

Methods

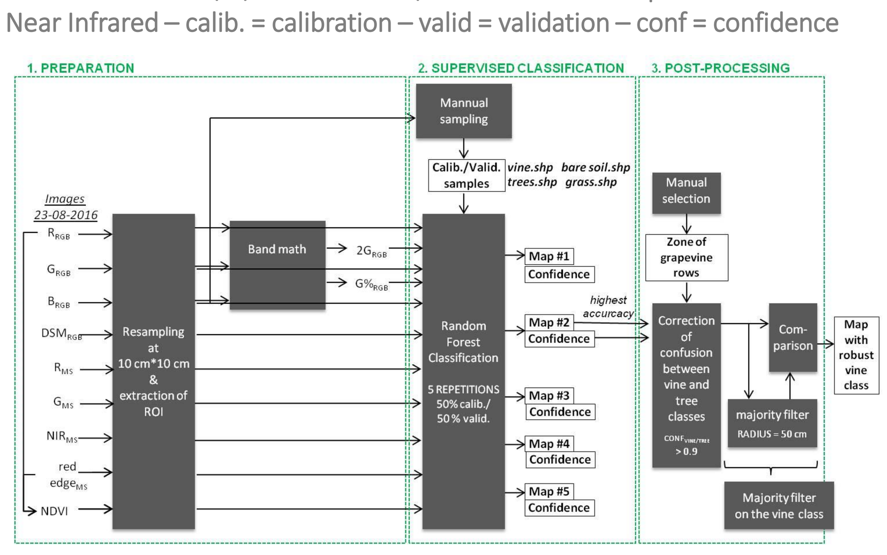
A two-step image analysis methodology was tested:

Step 1: Land cover mapping

1. Computation of the difference index (2G) and the green percentage index (G%) according to Poblete-Etcheverria et al. (2017);
2. Supervised classification by training a Random Forest (Breiman 2001);
3. Post-processing :
(i) masking of the limits of plots for re-attributing grapevine / tree classes.
(ii) and majority filtering applied specifically to the vine class so that only grapevine pixels being connected to other grapevine pixels are retained.

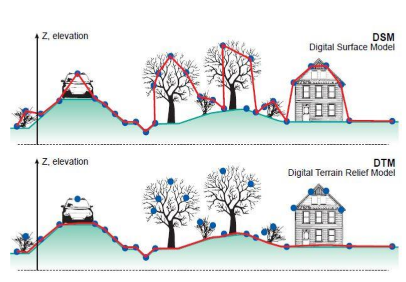
Tools: Python script calling the Orfeo ToolBox (OTB) (CNES 2018) and Geospatial Data Abstraction Library (GDAL) (GDAL/OGR contributors 2018)

Flow chart for mapping the land cover of agroforestry vineyards. Abbreviations: R/G/B = Red Green/Blue – MS = Multi Spectral – NIR = Near Infrared – calib. = calibration – valid = validation – conf = confidence



Step 2: vegetation height mapping

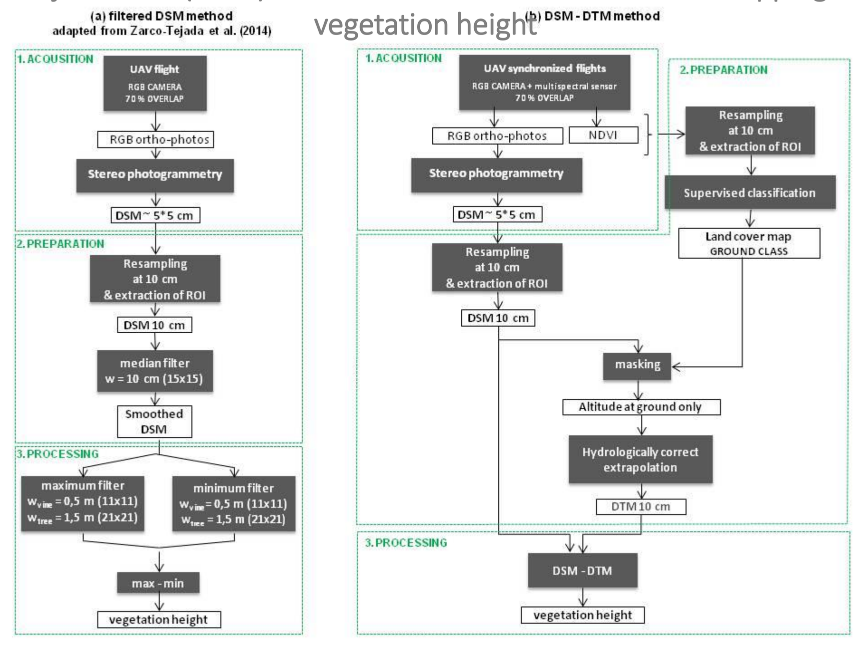
Vegetation height is mapped by subtracting a Digital Terrain Model (DTM) to the Digital Surface Model (DSM).



Two methods are compared:

- the *filtered DSM method* from Zarco-Tejada et al. (2014): only requires a high resolution DSM; $H_{vegetation} = DSM_{max} - DSM_{min}$
- vs. a *DSM-DTM method*: requires a high resolution DSM and the corresponding land occupation map. $H_{vegetation} = DSM - DTM_{extrapolation\ sol}$

Implementation of the filtered DSM method adapted from Zarco-Tejada et al. (2014) and of the DSM - DTM method for mapping vegetation height



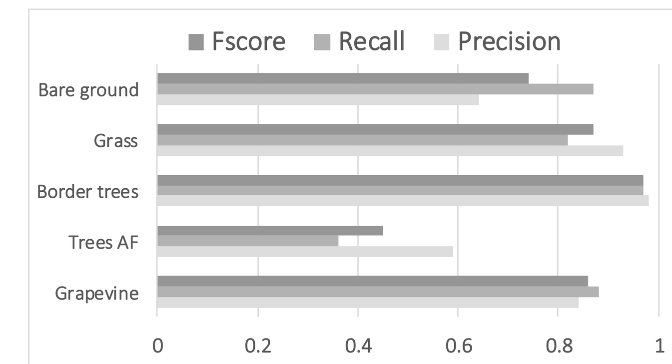
Results and discussion

Accuracy of vegetation classification

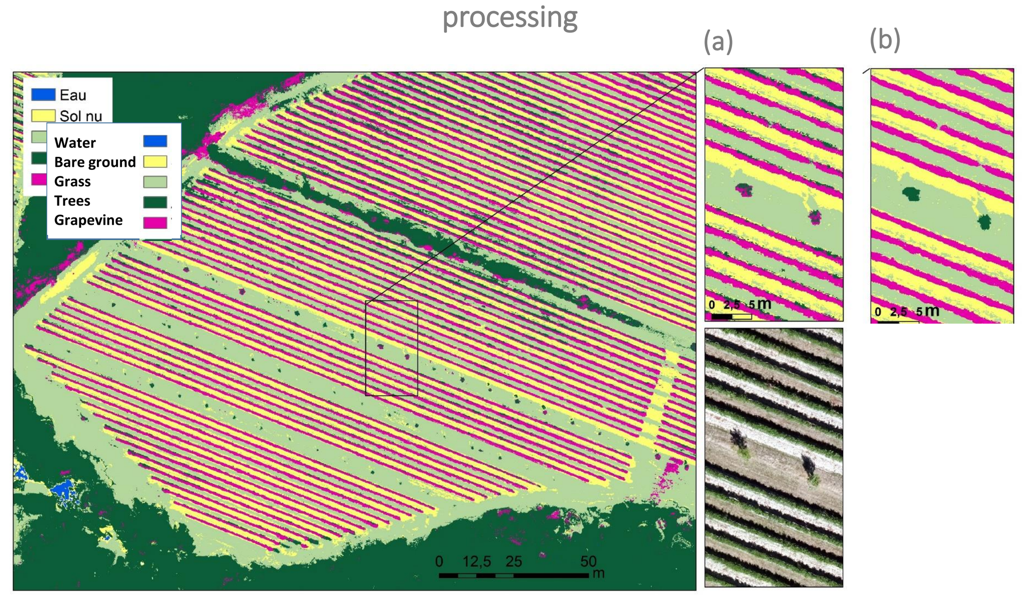
Overall accuracy of classification is satisfying. Nonetheless classes grapevine and trees show important confusion which justifies post-processing. Methodology is very conservative: branches of grapevine crossing middle rows have very low density of foliage but are classified as grapevine.

Classification scores at Lagardère on the 20 Jul. 2016

Overall accuracy : from 0.89 to 0.94 (5 runs)



Land cover map at Lagardère on the 20 Jul. 2016 (a) before and (b) after post-processing



Land cover map at the agroforestry vineyard of Restinclières on the 24 Aug. 2016 obtained from supervised classification.prior to post-processing

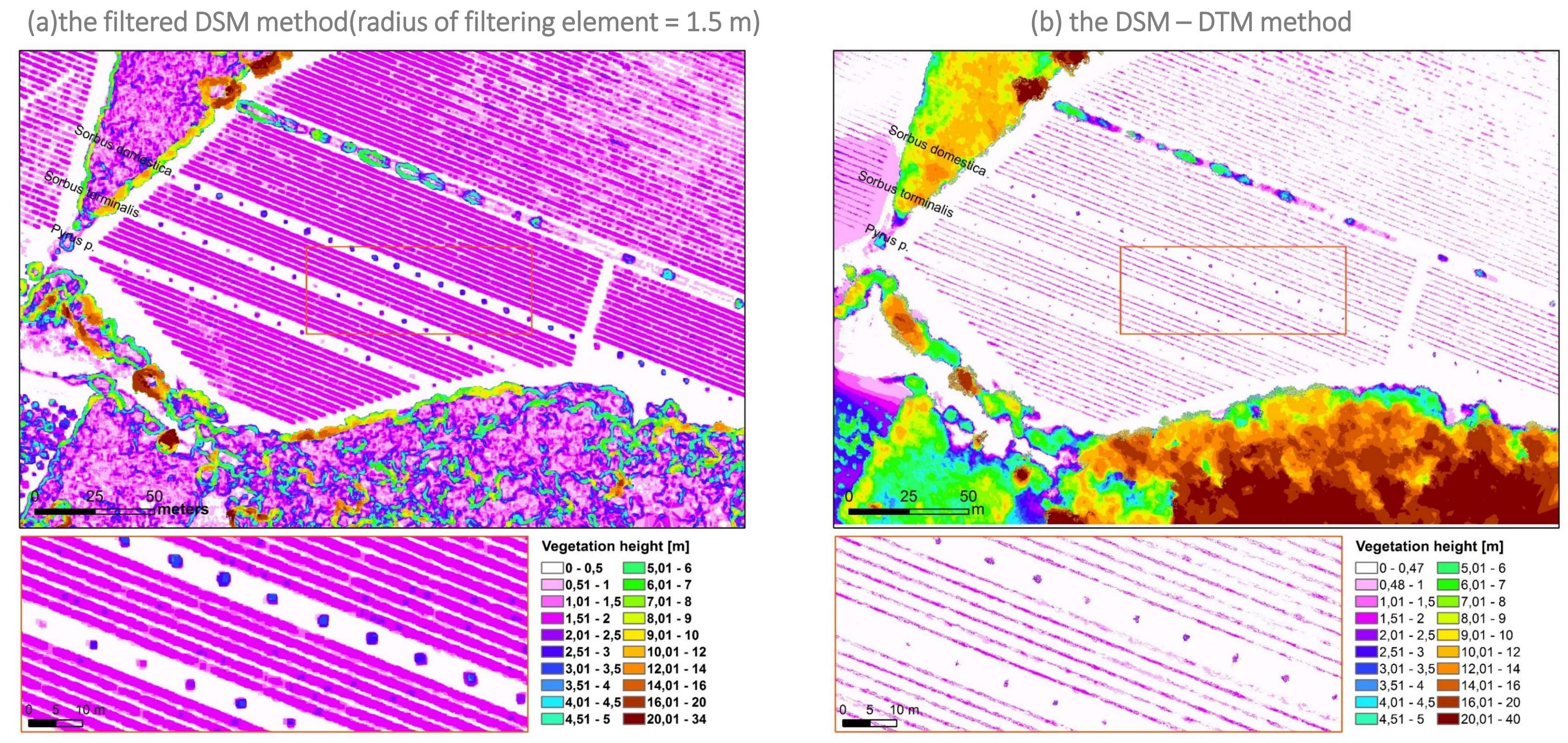
Accuracy of vegetation height maps

The DSM - DTM method shows several advantages compared to the filtered DSM method:

- it preserves vegetation borderlines;
- it improves the estimation of the height of forest trees when slope is relatively constant;
- it documents the variability in height within the crown of an isolated tree.

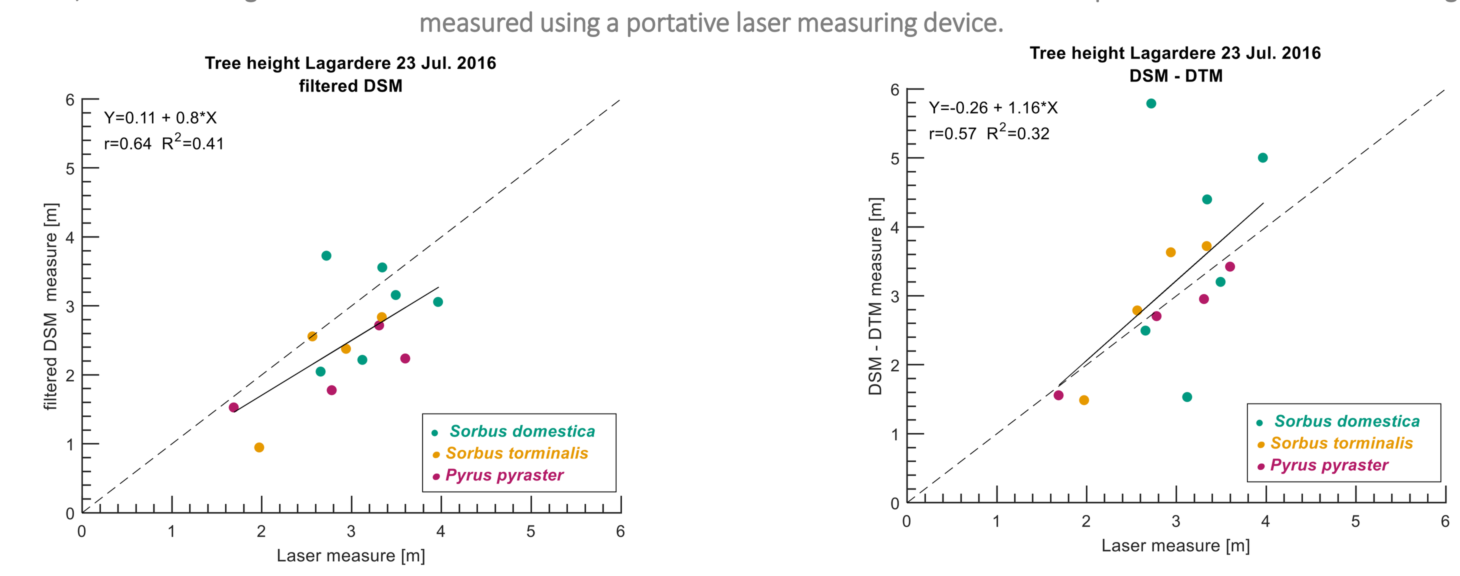
Vegetation height at Lagardère study vineyard on the 20 Jul. 2016 mapped by …

(a)the filtered DSM method(radius of filtering element = 1.5 m) (b) the DSM – DTM method



For most species of individual trees, the DSM-DTM method shows the highest overall accuracy for estimating tree height, based on laser-meter measures of reference. In the particular case of very small leaved trees (ex: *Sorbus domestica*), all methods including laser shows poor accuracy.

At Lagardère, estimated heights of a selection of isolated trees are extracted from the two sourced maps and confronted with the heights measured using a portative laser measuring device.



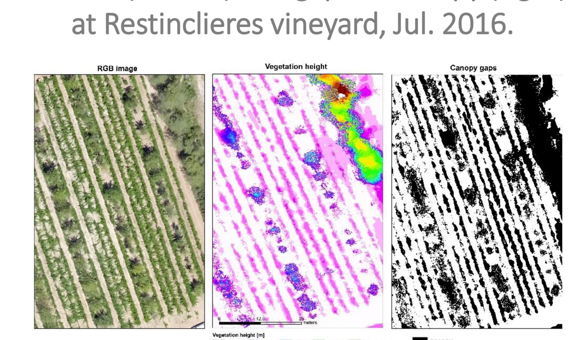
Conclusions and perspectives

The overall approach opens many potential applications for computing vegetation metric such as vegetation 3D density.

In addition, the newly proposed 'DSM-DTM' method is highly recommended for pixel-by-pixel applications.

The land cover mapping method could gain both accuracy and reproducibility considering only the images from the RGB sensor: indeed, testing a two-step classification with RGB bands and then RGB+DTM shows promising results for mapping foliage gaps more accurately.

Zooms on the RGB image (left), height of the vegetation retrieved by DSM-DTM method (middle) and gaps in canopy (right) at Restinclieres vineyard, Jul. 2016.



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