ASSESSING THE USE OF SENTINEL-2 TIME SERIES FOR MONITORING CORK OAK DECLINE IN PORTUGAL

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TEST SITE

The study was undertaken in an agro-silvo-pastoral system located in central Portugal, namely Herdade da Machoqueira do Grou (site HMG) (Figure 1). Herdade da Machoqueira do Grou, with an area of around 14.6 ha, is located at the left bank tributary of the Tagus River, approximately 100 km of Lisbon. This region is characterised by a mild Mediterranean climate with Atlantic influences. The bioclimate is considered semiarid to subhumid, with an average annual rainfall of 662.5 mm and a mean annual temperature of 16.3°C.

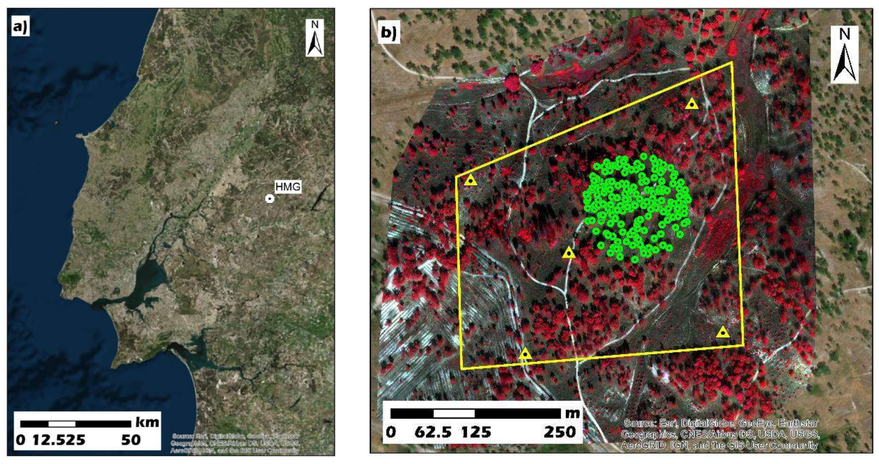
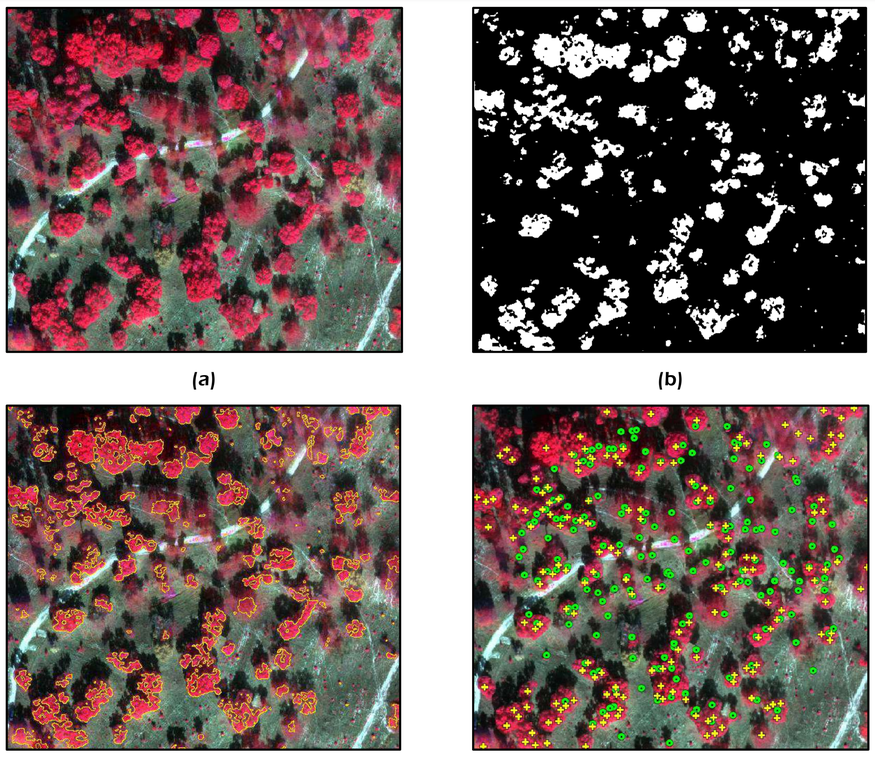


Figure 1. (a) Regional setting of the test site (white dot) approximately 100 km northeast of Lisbon; b) Herdade da Machoqueira do Grou (HMG). Yellow polygon represents the test site limits, yellow triangles the ground control points (CGPs) location and green circles the in-situ measurements location.

MATERIALS

- 2 UAV visible and near infrared (NIR) orthomosaics obtained using a senseFly eBee Classic drone equipped with a Parrot SEQUOIA sensor. Data were acquired, on June 26 and October 22, 2018, with 75% sidelap and 70% forward overlap at a flight altitude of around 140 m above ground level (AGL), with an average GSD of 0.12 m.
- 47 cloud-free level-2A Sentinel-2 (S2) images acquired from May 2017 to December 2018.
- In-situ measurements (location and phytosanitary condition of each tree) collected, in October 2018, at a 150-m diameter circular area (Figure 1b).



(a) (b) (c) (d)

Figure 2. HMG test site: (a) UAV false-colour composite image (NIR, R, G); (b) Binary image with the tree crowns (in white); (c) Tree crown´s delimitation (in yellow) superimposed on the false-colour composite; and (d) Individual tree location obtained using the developed algorithm (yellow cross) and coordinated at the field (green circles).

CONCLUSIONS

Preliminary results seem promising, especially when considering VCI that is useful for making relative assessments of changes in the NDVI signal. Relative measurements of the present vegetation condition against a reference condition are critical for understanding and quantifying real vegetation conditions, characterized by historical mean. Further work will focus on the use of machine learning algorithms, in particular random forest (RF), and also on linear discriminant analysis (LDA).

TREE CROWNS IDENTIFICATION

Statistics are applied based on the UAV orthomosaic's grayscale values distribution to determine whether a given pixel is in a tree or on the ground. NDVI (Rouse *et al.*, 1973), as an indicator of canopy structure and photosynthetic activity, and SAVI (Huete, 1988) that improves the sensitivity of NDVI to soil backgrounds were used.

A locally adaptive threshold is then computed based on the local mean intensity (local first-order statistics) in the neighbourhood of each pixel, separating the foreground from the background with non uniform illumination (Figure 2b). Grayscale images were downscaled to 0.36 m and size of the neighbourhood used to compute local statistic was set as 11x11. Next, a low-pass filtering was applied to remove noise and the binary image was converted into a polygon vector file (Figure 2c).

Polygons with an area less or equal to 20 m^2 were identified as isolated trees, while for the remaining polygons the Euclidean distance of the binary file was calculated. The maximum value for the Euclidean distance within each polygon was 25 pixels corresponding to 9 m. Individual trees location was determined as the maximum of the distance function inside each isolated polygon, whilst for the case of tree clusters, the local maximum of the distance function was considered (Figure 2d). In the latter case, local maximum values must exhibit a distance greater than the minimum distance between trees, set as 2 m.

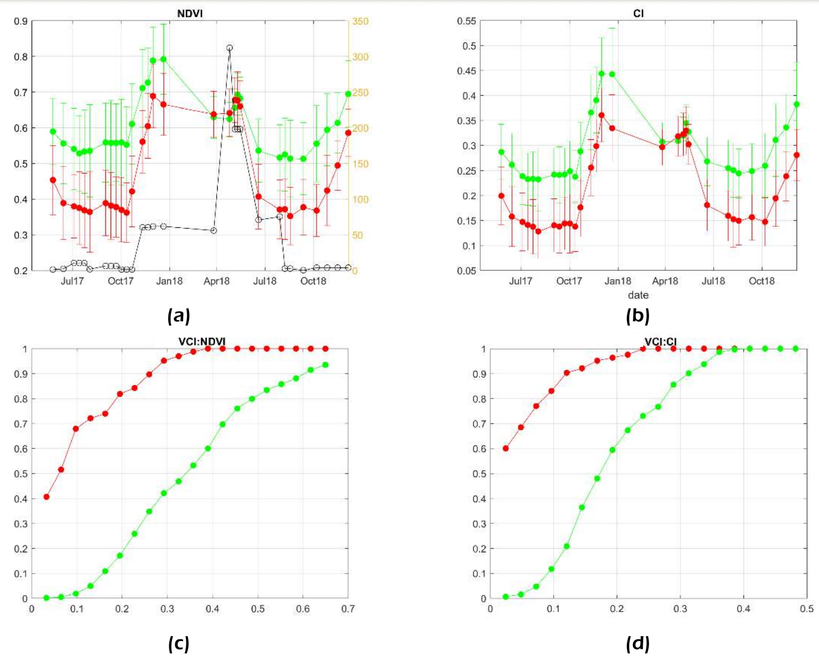


Figure 3. Healthy (green) and unhealthy (red) cork oak trees temporal variability computed based on the NDVI (a) and CI (b) indices. Monthly precipitation values are superimposed to the NDVI time series (a). Cumulative distribution function (CDF) applied to the VCI/NDVI ratio (c) and to the VCI/CI ratio (d).

CORK OAK TREES SPECTRAL TEMPORAL VARIABILITY

Cork oak temporal variability was evaluated using vegetation indices (VI) time series calculated from the Sentinel-2 images. The VI used in this study were the NDVI (Rouse *et al.*, 1973), the NDWI (Gao, 1996), the GNDVI (Gitelson and Merzlyak, 1996), the red-edge Chlorophyll Index, CI (Zarco-Tejada *et al.*, 2001) and the Vegetation Condition Index, VCI (Kogan, 1990, 1995). Two sets of trees were established based on their degree of defoliation: healthy (less than 50%) and unhealthy (higher than 51%) trees.

The phenological behaviour of healthy and unhealthy trees is significantly distinct from July to October, while during winter months both trees exhibit almost the same behaviour (Figure 3a and 3b). Since unhealthy or dead trees show, respectively, little or absent photosynthetic activity, one can conclude that this increase in the VI values results from an increase in understory production due to precipitation, which in turn causes a significant contribution of the understory (or forest floor) spectral reflectance in the NIR region.

In order to separate healthy from unhealthy trees, a univariate analysis was performed. The threshold for the spectral separability between the two status classes was established by comparing the cumulative distribution function (CDF) for different VI. Thresholds were defined as the values for which the commission error is lower than an a priori established value. CDF results for the VCI show a notorious discrimination between healthy and unhealthy cork oak trees. Considering a commission error of 10%, a value of 0.16 was obtained for the VCI/NDVI ratio, with an omission error of 25% (Figure 3c), and a value of 0.10 for the VCI/CI ratio, with an omission error of 18% (Figure 3d).

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