remote sensing

MDPI

Supplementary Materials

Using Digital Photography to Track Understory Phenology in Mediterranean Cork Oak Woodlands

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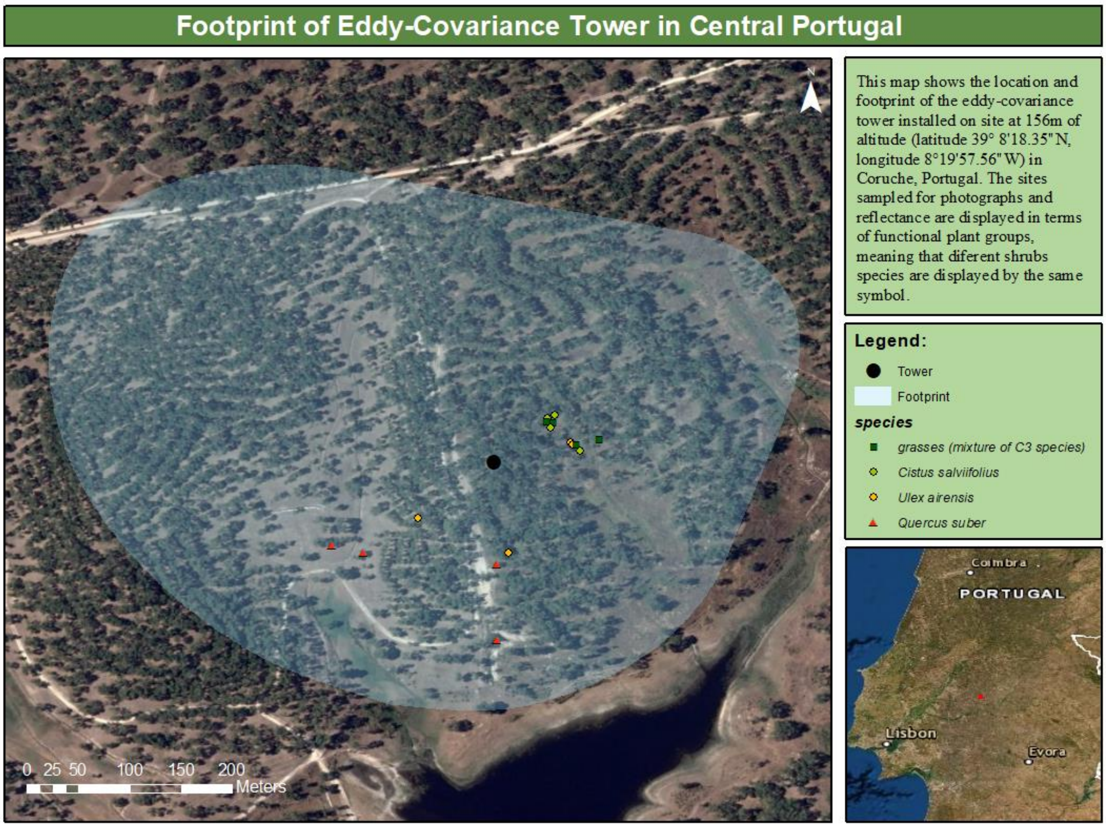
Abstract: Monitoring vegetation is extremely relevant in the context of climate change, and digital repeat photography is a method that has gained momentum due to a low cost–benefit ratio. This work aims to demonstrate the possibility of using digital cameras instead of field spectroradiometers (FS) to track understory vegetation phenology in Mediterranean cork oak woodlands. A com-mercial camera was used to take monthly photographs that were processed with the Phenopix package to extract green chromatic coordinates (GCC). GCC showed good agreement with the normalized difference vegetation index (NDVI) and normalized difference water index (NDWI) obtained with FS data. The herbaceous layer displayed a very good fit between GCC and NDVI (coefficient of determination, represented by r2 = 0.89). On the contrary, the GCC of shrubs (Cistus salviifolius and Ulex airensis) showed a better fit with NDWI (r2 = 0.78 and 0.55, respectively) than with NDVI (r2 = 0.60 and 0.30). Models show that grouping shrub species together improves the predictive results obtained with ulex but not with cistus. Concerning the relationship with climatic factors, all vegetation types showed a response to rainfall and temperature. Grasses and cistus showed similar responses to meteorological drivers, particularly mean maximum temperature (r = −0.66 and −0.63, respectively). The use of digital repeat photography to track vegetation phe-nology was found to be very suitable for understory vegetation with the exception of one shrub species. Thus, this method proves to have the potential to monitor a wide spectrum of understory vegetation at a much lower cost than FS.

Keywords: digital repeat photography; green chromatic coordinates; spectral vegetation indices; monitoring vegetation; Mediterranean cork oak woodlands



This map shows the location and footprint of the eddy-covariance tower installed on site at 156m of altitude (latitude 39° 8'18.35" N, longitude 8°19'57.56" W) in Coruche, Portugal. The sites sampled for photographs and reflectance are displayed in terms of functional plant groups, meaning that diferent shrubs species are displayed by the same symbol.

Figure S1. Graphical abstract of the work illustrating the methodology, the area covered and the species sampled on site. Note that the location of *Quercus suber* is accessory.

Correlation Matrix between GCC and Spectral VIs: grasses

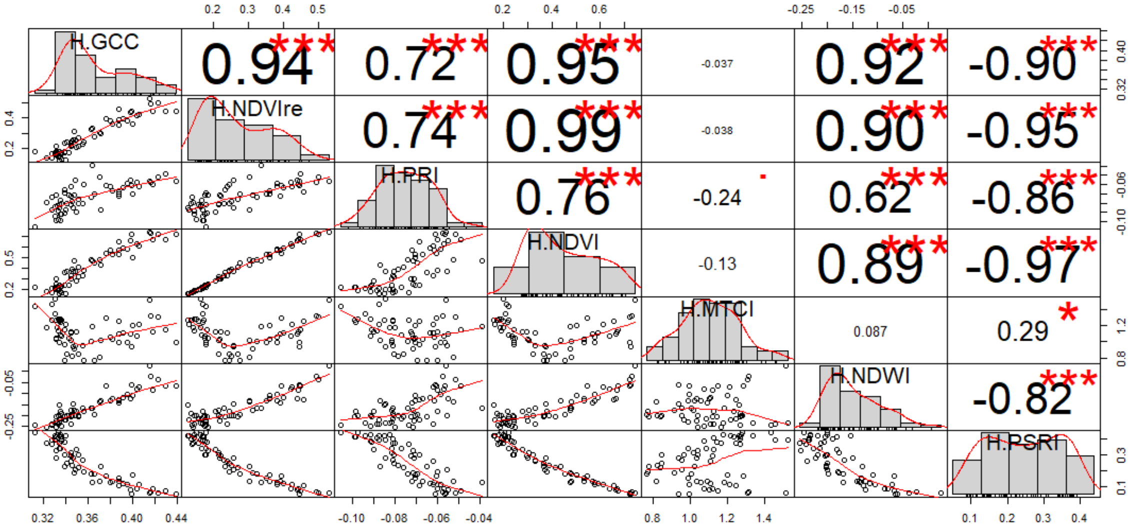


Figure S2. Grasses are represented by the capital letter H, for herbaceous layer, and spectral VIs are: NDVIre (Red-Edge Normalized Difference Vegetation Index), PRI (Photochemical Reflectance Index), NDVI (Normalized Difference Vegetation Index), MTCI (MERIS Terrestrial Chlorophyll Index), NDWI (Normalized Difference Water Index) and PSRI (Plant Senesce Reflectance Index). The center diagonal shows a frequency histogram, the bottom half graphs the point cloud and the top half has the corresponding Pearson correlation coefficient (r). Significance is higher according to the number of red asterisk (*). Three asterisk indicates $p < 0.001$, two $p < 0.01$, one $p < 0.05$ and the dot $p < 0.1$.

Correlation Matrix between GCC and Spectral VIs: cistus

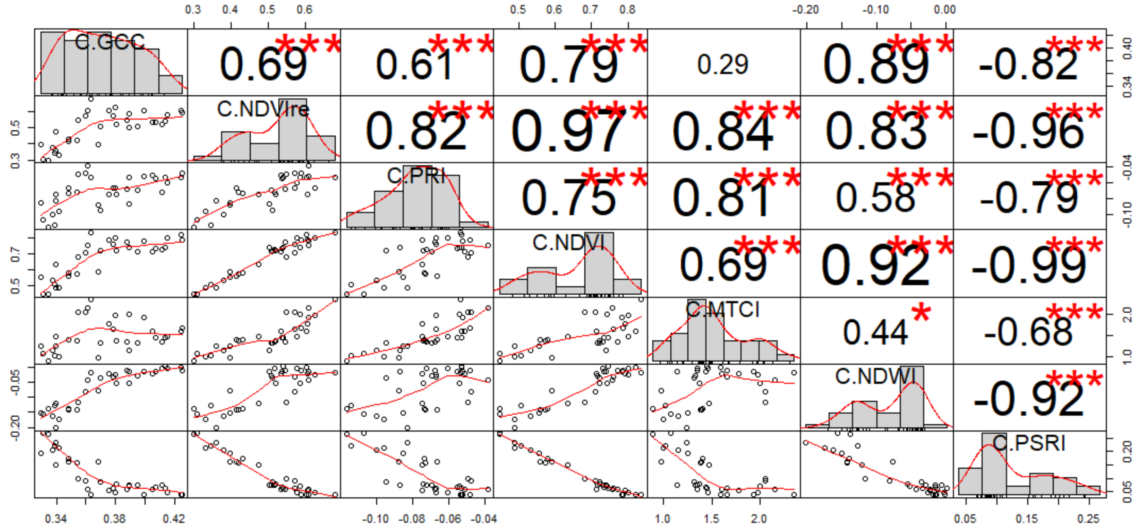


Figure S3. *Cistus salviifolius* is represented by the capital letter C and spectral VIs are: NDVIre, PRI, NDVI, MTCI, NDWI and PSRI, defined in Figure S2. The information in the center diagonal, bottom and top half of the graph, as well as significance, are labelled in Figure S2.

Correlation Matrix between GCC and Spectral VIs: ulex

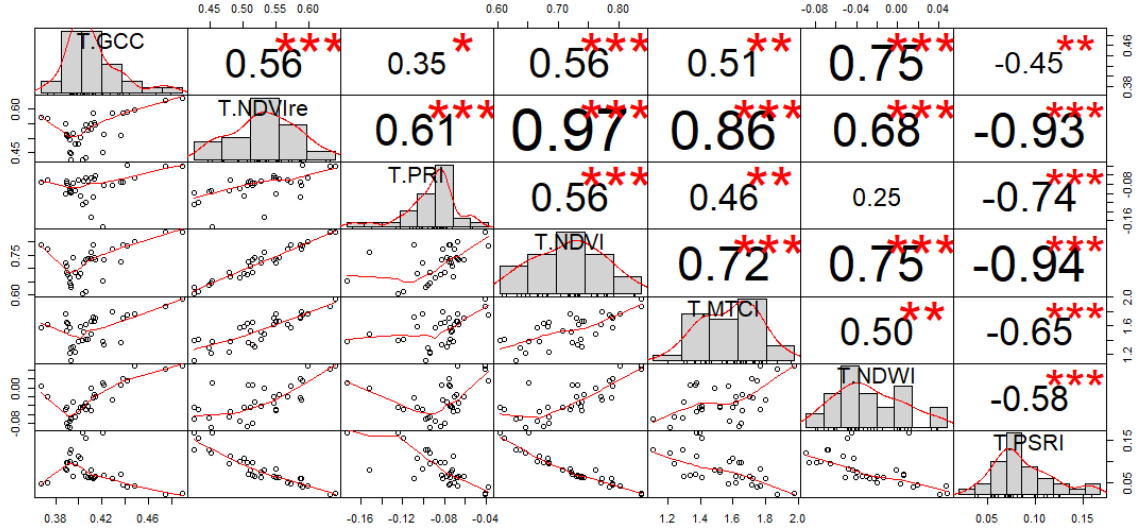


Figure S4. *Ulex airensis* is symbolized by the capital letter T (after the Portuguese common name for the species, “Tojo”) and spectral VIs are: NDVIre, PRI, NDVI, MTCI, NDWI and PSRI, defined in Figure S2. The information in the center diagonal, bottom and top half of the graph, as well as significance, are labelled in Figure S2.

Interannual Relationship between Indices

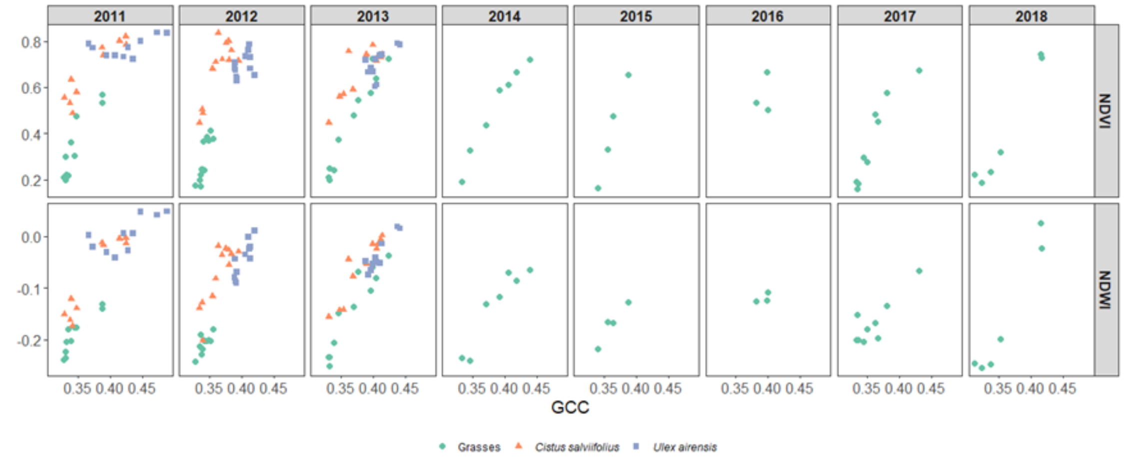


Figure S5. The interannual relationship between GCC and spectral VIs for grasses (green dots), cistus (red triangle) and ulex (purple square). Each point is a daily mean value.

Correlation Matrix between VIs and Precipitation

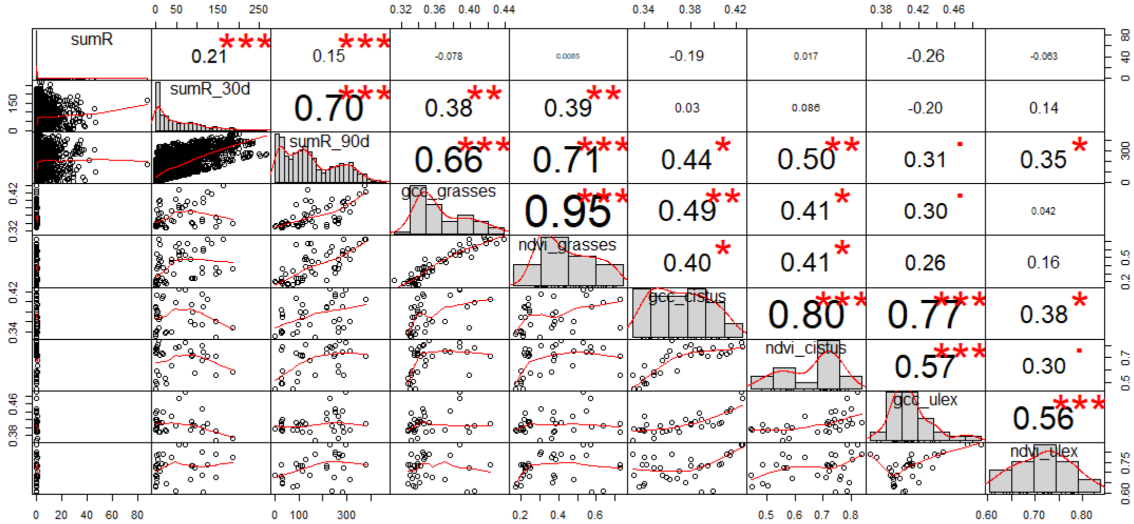


Figure S6. Shows the correlation between GCC, NDVI and precipitation: at time-lags 0, 30 and 90. The vegetation types are grasses, cistus and ulex. Information in the center diagonal, bottom and top half of the graph, as well as significance, are labelled in Figure S2.

Correlation Matrix between VIs and Temperature

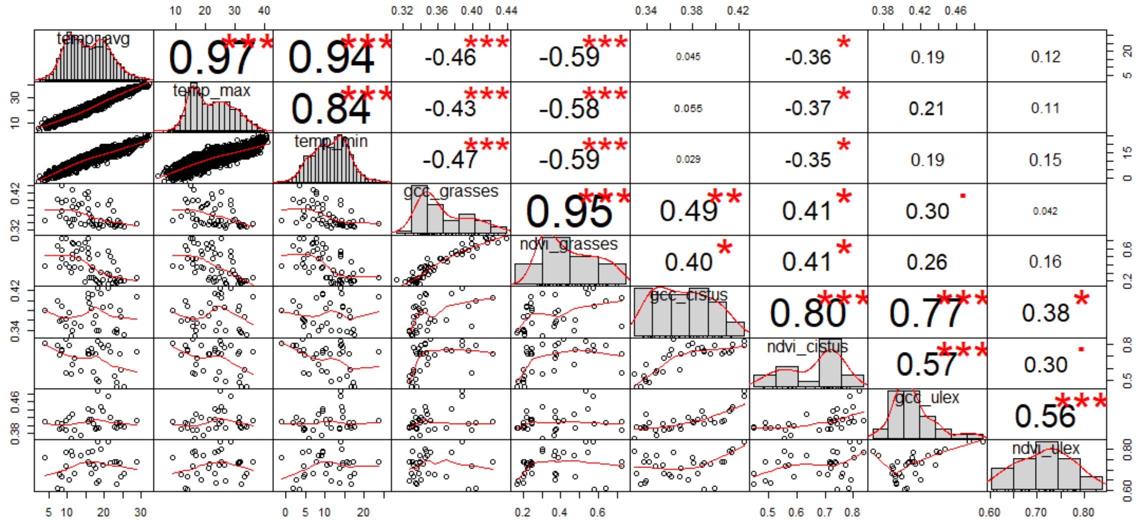


Figure S7. The correlations between GCC, NDVI and temperature: average, maximum and minimum. The vegetation types are grasses, cistus and ulex. Information in the center diagonal, bottom and top half of the graph, as well as significance, are labelled in Figure S2.

Correlation Matrix between VIs and Temperature: time-lag 30

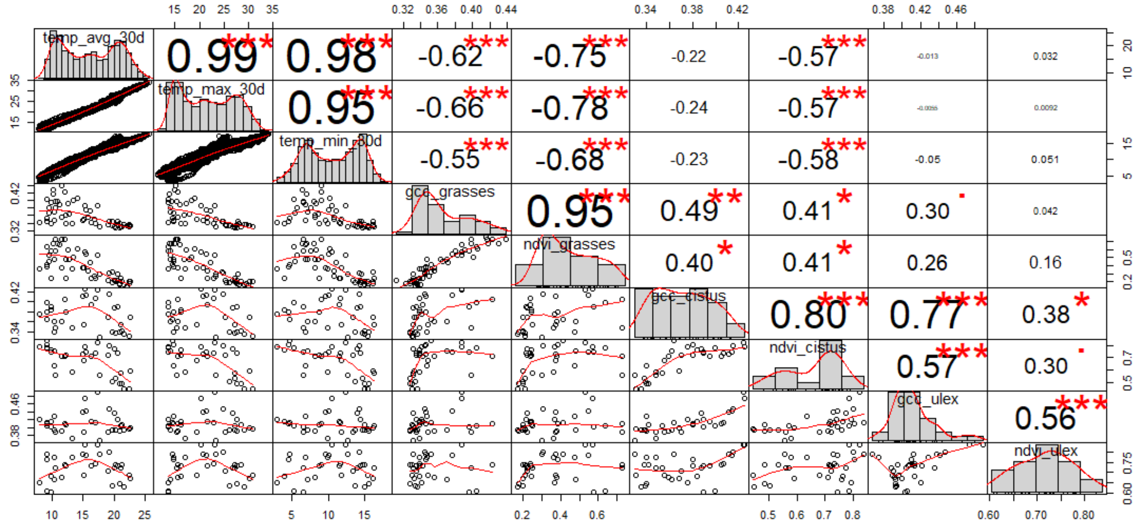


Figure S8. The correlations between GCC, NDVI and temperature: average, maximum and minimum at time-lag 30. The vegetation types are grasses, cistus and ulex. Information in the center diagonal, bottom and top half of the graph, as well as significance, are labelled in Figure S2.

Correlation Matrix between VIs and Temperature: time-lag 90

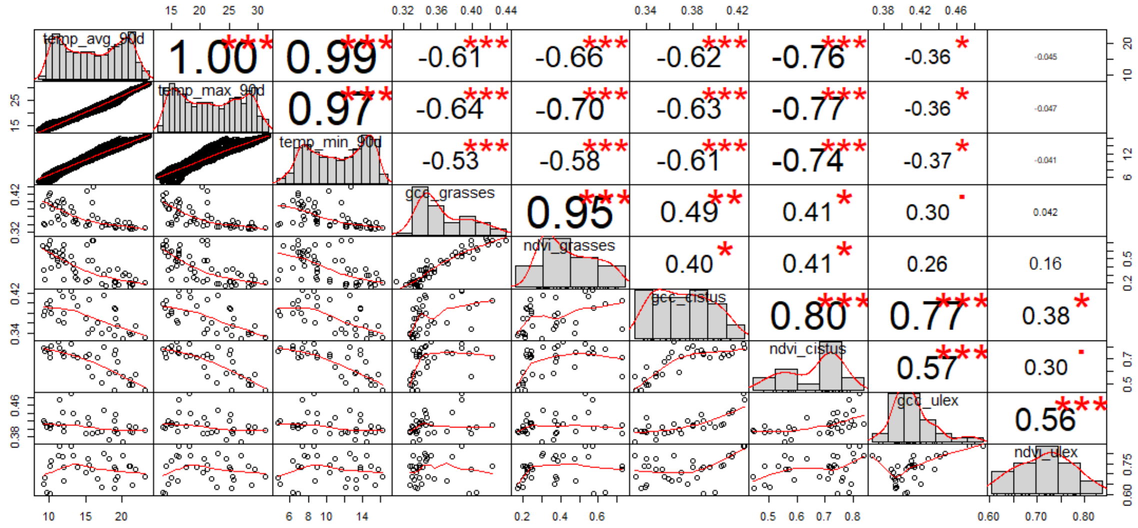


Figure S9. The correlations between GCC and temperature: average, maximum and minimum at time-lag 90. The vegetation types are grasses, cistus and ulex. Information in the center diagonal, bottom and top half of the graph, as well as significance, are labelled in Figure S2.