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| **Detecting drought stress using machine learning and hyperspectral drone imagery in a mixed Mediterranean forest** |
| **Introduction/Aim:**  Forests increasingly face drought, leading to trees' vulnerability to pests, diseases, and eventually death. Monitoring the water status of forest trees across large spatial scales is crucial for management and conservation. Leaf water potential (leaf) is a vital metric for characterizing tree drought stress and is thus used as an early warning signal. However, measuring leaf is time-consuming and, hence, limited to a relatively small area. Remote sensing enables rapid and non-invasive assessment of vegetation characteristics. Previous studies have shown the potential for using remote sensing spectral vegetation indices to assess leaf across vegetation types. Yet, this method was not tested in diverse, mixed-species forests at high spatial resolutions. Also, studies have yet to combine such data with machine learning (ML) to predict leaf.  We used high-resolution drone images to assess leaf in five key woody Mediterranean species. We developed ML models and compared them with traditional spectral indices. We also tested an ML classification model to determine whether it can distinguish between trees suffering from stress and those that do not.  **Methods:**  Six experimental plots (*c.* 0.05 ha each) were set in a mixed Mediterranean forest in central Israel (Yishi Forest). Rain shelters were placed beneath the canopies in three plots to reduce rain by *c.* 50%. Each plot had the five woody species that compose the mixed forest – *Pinus halepensis*, *Quercus calliprinos*, *Cupressus* *sempervirens*, *Ceratonia siliqua*, and *Pistacia* *lentiscus*. Five leaves from 3 individuals were sampled per each co-occurring woody species. leaf measurements were conducted between 9 am and 1 pm once every two weeks using a pressure chamber from October 2022 to March 2023. On the same day, hyperspectral images were taken at 60 m height using a Headwall Photonics nano-hyperspec camera onboard a DJI Matrice 600Pro drone. The background and shades were removed from the images using NDVI and NIR thresholds. leaf was correlated with 12 spectral indices, thousands of normalized difference spectral index (NDSI) combinations, and ML models fed with the hyperspectral data. We also applied an ML classification model to assess whether trees in the drought plots can be distinguished from those in the control.  **Results:**  leaf ranged between –1.0 MPa in unstressed trees and –5.0 MPa in rain-deprived *Cupressus* *sempervirens.* ML models showed only slight improvement compared to simple linear regressions of the commonly used spectral indices with leaf. The best model was derived from plot-level regressions with all species (R2 = 0.8, RMSE = 0.31 MPa). The ML classification model using seven running averages over 40 bands had an accuracy of 88% and F1 of 0.88 in detecting trees suffering from drought stress (trees in reduced rainfall plots), even though physiological metrics showed little or no significant response.  **Conclusion:**  Our leaf ML model can be used with satellite data across sites since the best model was exerted on the plot level with all species combined. The ML classification model showed promising results in detecting early responses to drought, facilitating timely forest management practices like thinning or selected logging. |