Assessing Olive Trees Health using Vegetation Indices and Mundi Web Services for Sentinel-2 Images

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Abstract. A variety of plant protection approaches exists to aid against pests and diseases, and they all converge in recognizing early and precisely plant stress to make applications more effective and as low-cost as possible. Consecutive advances on the field of remote sensing regarding sensor quality, data availability, procurement costs and development of smart agricultural services have enhanced the ability to assess and monitor crop health, both in individual plants and field levels. In this work, a methodology to create a detection model for olive tree stress status based on Sentinel-2 data is presented. Vegetation indices were created based on the acquired data and are presented as intermediate results of analysis in order to enhance the assessment of health status. These extracted data will be used to train and validate a machine learning classification model. The resulting model will be able to support agriculture professionals by enhancing their decisions and investigations.

Keywords: Remote Sensing; Plant Stress; Vegetation Index; WMS; FIS; DIAS Mundi.

1 Introduction

Plant diseases have constantly been a significant concern for horticulture since they strongly and adversely affect production and quality of products. Impacts of biotic crop stress such as diseases and pests, fluctuate from minor side effects to extreme losses of whole yields, which bring about major expenses for agricultural businesses and affect intensely agricultural economy, particularly in developing countries that rely upon a single or a small number of crops.

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Evading these significant disasters can be accomplished by various strategies focusing on timely stress factor identification. In any case, it is difficult for growers to apply these strategies, as a significant number of them are inaccessible and regularly require explicit domain knowledge and are, often, costly and resource-heavy to complete.

Absence of reliable, dedicated and far reaching services restricts growers' actions in being proactive in their efforts against epidemics containment, as detection at ground-level is hard to apply continuously and consistently.

The usefulness in the utilization of sensors, mainly optical, to accurately detect plant diseases is recognized by Kuska and Mahlein (2018). The necessity to address the difficulties to be resolved in the application of such techniques for increasingly efficient plant disease protection is also recognized.

Hornero *et al*. (2018) also used Sentinel-2 data to calculate spectral indices able to provide spatio-temporal indications for tracing and mapping *Xylella fastidiosa* damage.

In the research carried out by Yuan *et al*. (2017) the capacity of satellite information to monitor pests and diseases is also shown. They used a combination of remote sensing data with different spatial resolution, Worldview 2 and Landsat 8, in order to compute a combination of vegetation indices and environmental features.

Immitzer, Vuolo and Atzberger (2016) in their work, utilized preliminary Sentinel-2 data and a variety of analysis approaches to map vegetation in order to produce land cover maps. Part of their research aimed at using the Sentinel-2 data to discriminate between crop types and part at differentiating between seven deciduous and coniferous tree species for forest management. Their results suggest that high accuracies can be achieved for many of their utilized analysis methods.

The aim of this work was to use Sentinel-2 derived Vegetation Indices to provide insight for stress detection in olive trees.

2 Utilized Datasets & Sampling Procedure

All disease symptoms are attributed to anatomical and physiological deteriorations which, as a result, differ from the typical reflectance of a healthy plant. Additionally, these deteriorations are often correlated with fluctuations in the concentration of chlorophyll and carotenoids in plant tissues.

Chlorophyll and carotenoid concentration can be more easily correlated in specific spectral regions such as green, red, red-edge and near infrared.

The samples used for analysis were square polygons (sampling units) and the ground truth data accompanying them is biotic and abiotic stress-related assessments carried out by visual inspection of the present symptoms. Accompanying the assessments is a list of factors which heavily affect reflectance data from the sampling units. These are ground cover vegetation, tree biomass and irrigation of the crop, as well as, the variety of the assessed trees. Vegetation present in the ground is always included in the reflectance value of each pixel and accounts for all reflectance corresponding to the sampling unit that is not attributed to tree foliage. Recording this list of factors can further support data analysis and support the final conclusions.

To acquire data from the wavelengths of interest Sentinel-2 images from Halkidiki, Northern Greece were accessed. The Copernicus programme through the Sentinel-2 missions offers detailed and timely information that can be used for vegetation imaging, soil and water cover, inland waterways and coastal areas or to deliver information for emergency services.

Sentinel-2 is a polar-orbiting, multispectral, high-resolution, imaging mission used for crops and farmland applications. Additionally, it currently consists of a constellation of two satellites, Sentinel-2A and Sentinel-2B, allowing for a revisit time of five days under the same viewing conditions, in most regions.

At this time, the free downloadable content provides ready-to-use bottom of atmosphere products (Level 2A) in 13 bands, with a maximum spatial analysis of 10-m for Blue, Green, Red and Near Infrared bands. Level 2A products from Sentinel-2A and 2B are atmospherically corrected and the data are immediately available for download and ready for analysis.

The services for accessing satellite data is offered by EUXDAT, an online platform developed in the frame of the European H2020 project aiming at providing efficient and easy way to access and process remote sensing data for the agricultural domain. EUXDAT relies on Mundi DIAS to access a comprehensive database of Sentinel products.

3 Tools & processing

The objective of data analysis is to assess for each pixel the incidence and severity of stress and subsequently provide similar quantitative information for a given field. Various vegetation indices were calculated for the sampling units. The use of multiple vegetation indices is deemed important to compute and assess for the detection of stress.

These indices can be used to classify each pixel to one of two classes; stress incidence, caused by various biotic and abiotic factors, or lack thereof.

The analyzed data were accessed by Web Map Service (OGC WMS standard) and Feature Info Service (Sentinel Hub FIS standard) requests on the EUXDAT platform.

WMS requests, by defining a geographic layer and area of interest to be processed, allow for faster acquisition, lighter storage requirements and easier analysis. An advantage of this service is that it provides a geo-referenced map image (JPEG, GeoTiff, PNG) that can be displayed in a browser application, and thus only the image in the area of interest and the desired bands can be downloaded and not entire tiles. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not.

The feature info service (FIS) performs elementary statistical computations — such as mean, standard deviation, and histogram approximating the distribution of reflectance values — on remotely sensed data for a region specified in a given spatial reference system and across different bands and time ranges. This step facilitates access to specific pixels, rather than entire images, thus making the data processing more effective.

A typical application example would be querying the service for basic statistics and the distribution of NDVI values for a polygon that represents an agricultural unit over a time range.

4 Preliminary Results

Below, the generated vegetation indices are listed, with their values corresponding to Sentinel-2 band reflectance relevant for their calculation. The selected indices provide important insight in vegetation reflectance fluctuations associated with different sources of stress.

Table 1. Vegetation indices tested on samples from the test area (Halkidiki). B02-B08 refer to the bands of Sentinel-2.

Vegetation Index		Index Formula	MIV* of all Stressed samples	MIV* of all Healthy samples	
NDVI	Normalized Difference Vegetation Index	(B08 - B04) / (B08 + B04) .	0.0482	0.0307	(1)
RDVI	Renormalized Difference Vegetation Index	(B08 - B04) / sqrt(B08 + B04) .	0.0317	0.0205	(2)
GNDVI	Green Normalized Difference Vegetation Index	(B08 - B03) / (B08 + B03) .	0.1379	0.1051	(3)
SAVI	Soil Adjusted Vegetation Index	(B08 - B04) / (B08 + B04 + 0.5) * (1.0 + 0.5) .	0.0334	0.0217	(4)
EVI	Enhanced Vegetation Index	2.5 * ((B08 - B04) / (B08 + (6 * B04) - (7.5 * B02) + 1)) .	0.0432	0.0299	(5)
TVI	Transformed Vegetation Index	sqrt(((B08 - B04) / (B08 + B04)) + 0.5) .	0.7402	0.7282	(6)
ARI1	Anthocyanin Reflectance Index 1	(1 / B03) - (1 / B08) .	1.4346	1.1635	(7)
ARI2	Anthocyanin Reflectance Index 2	B08 * ((1 / B03) - (1 / B08)) .	0.3238	0.2424	(8)
CRI1	Carotenoid Reflectance Index 1	(1 / B02) - (1 / B03) .	0.0980	-0.1515	(9)
CRI2	Carotenoid Reflectance Index 2	(1 / B02) - (1 / B08) .	1.5326	1.0120	(10)

*Mean Index Value

Fig. 1. EVI index showcasing plant stress in Halkidiki.

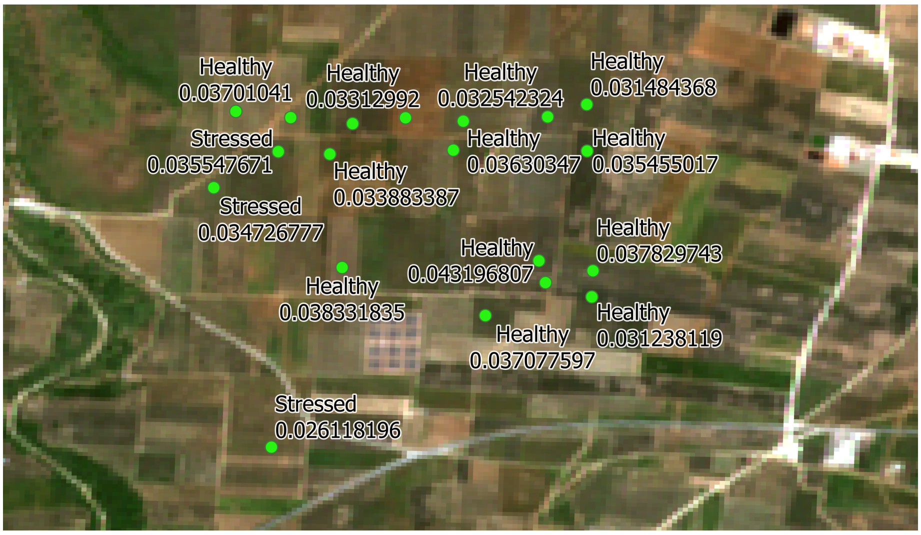

Fig. 2. NDVI values accompanying ground truth data.

The figures above display sampling points from the test area on Halkidiki. The status of sampling points, being Healthy or Stressed can be shown, together with the values of EVI (Fig. **1**) and NDVI (Fig. **2**) as indicators of their health status based on Sentinel-2 reflectance data. This kind of depiction can help corroborate ground truth with use of the vegetation indices calculated.

By utilizing vegetation indices as showcased in Fig. **1** and Fig. **2**, advisors and growers are given the ability to assess which spots are highlighted as stressed or not, and what is the accompanying value of the relevant vegetation index. They can then act according to that knowledge.

5 Discussion & Conclusions

The presented work can assist to the identification of stresses in olive tree. Considering the frequent revisit time of the Sentinel-2 satellites, it can contribute to an early warning system for olive trees stress.

The presented vegetation indices will be used in the process of training a support vector machine (SVM) model to classify each pixel to one of the two categories, healthy or stressed. Development of this process is being carried out by using Jupyter Lab with Python 3 programming environment and the relevant libraries available for accessing, acquiring, processing and modeling the data.

The resulting model is expected to produce maps showcasing potentially stressed olive fields across a large area and in a small amount of time. This map can be used as a guide for further investigation by local agronomists of identified stressed fields or highlight areas of, previously non-existent, stressed fields. Thus, local agronomists and producers can benefit from the early detection of stress and by enacting more relevant agricultural investigations and applications.

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References

1. Hornero, A. et al. (2018) 'Using Sentinel-2 imagery to track changes produced by Xylella fastidiosa in olive trees' Department of Geography , Swansea University , SA2 8PP Swansea , UK Instituto de Agricultura Sostenible (IAS), Consejo Superior de Investigaciones Científicas (CSIC', pp. 9060–9062.
2. Immitzer, M., Vuolo, F. and Atzberger, C. (2016) 'First experience with Sentinel-2 data for crop and tree species classifications in central Europe', Remote Sensing, 8(3). doi: 10.3390/rs8030166.
3. Kuska, M. T. and Mahlein, A. K. (2018) 'Aiming at decision making in plant disease protection and phenotyping by the use of optical sensors', European Journal of Plant Pathology. European Journal of Plant Pathology, pp. 1–6. doi: 10.1007/s10658-018-1464-1.

4. Yuan, L. et al. (2017) 'Habitat monitoring to evaluate crop disease and pest distributions based on multi-source satellite remote sensing imagery', Optik. Elsevier GmbH., 145, pp. 66–73. doi: 10.1016/j.ijleo.2017.06.071.