

OLIVE TREES STRESS DETECTION USING SENTINEL-2 IMAGES

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ABSTRACT

In the field of plant disease protection many approaches exist, but all acknowledge the necessity of fast and accurate identification of the source in order to make the most efficient applications. In this work, a remote sensing approach for the detection of *Verticillium dahliae* in olive fields is presented. A model was created that calculates a spectral index based on Sentinel-2 data and uses it to assess the levels of stress in olive trees in the region of Chalkidiki, Greece. The derived map provides an overview of the situation concerning stress levels in olive fields across a large area and in a small amount of time. Additionally, because of the constant flow of data from the Sentinel satellites, a time series of calculations can be used as an anomaly indicator for regions of interest. This model can be implemented in an e-Infrastructure as a cloud service to further enhance its usability by relevant parties, such as agricultural advisors and scientists.

Keywords – satellite imaging, multispectral imaging, monitoring, plant phenotyping, spectral indices

1. INTRODUCTION

Agriculture is a vital industry that supports and employs millions of professionals and scientists worldwide. It is also, a definitive factor for nourishment and, simultaneously, health, economic and political stability, employment, business and biological ecosystems, and society. Due to its prevalent role, most attention focuses on productivity maximization, but a global view is essential for addressing environmental sustainability problems. It is vital for the current situation to be analysed and, as a result, manage to overcome computation and data scalability problems in subsequent years.

Olive tree cultivation accounts for nearly 2 billion euros in annual net income. Verticillium Wilt (VW) is an elusive olive tree disease and thus is difficult to be traced by simple human observation, especially at early stages. As a result, the farmers either are not reacting at all, or they are following ad hoc solutions in order to protect their trees

from VW. The lack of dedicated, comprehensive and reliable services prohibits farmers' efforts in being proactive in their efforts against the disease, as ground-level monitoring continuously and effectively is difficult.

For the purposes of the EUXDAT project (<http://www.euxdat.eu>) an e-Infrastructure, which addresses agriculture, land monitoring and energy efficiency will be developed, as a way to support planning policies. To achieve this, the services will be developed on existing mature components for solving them, by providing an advanced frontend, where users will develop applications on top of an infrastructure based on HPC and Cloud.

EUXDAT will include a large set of data connectors (UAVs, Copernicus, field sensors, etc.), for scalable analytics. It will use monitoring and profiling information for taking decisions based on trade-offs related to cost, data constraints, efficiency and resources availability.

During the project, EUXDAT will be in contact with scientific communities, in order to identify new trends and datasets, for guiding the evolution of the e-Infrastructure. The final result of the project will be an integrated e-Infrastructure which will encourage end users to create new applications for sustainable development.

Kuska and Mahlein [1] have identified the usefulness in the use of sensors, mainly optical, to precisely detect plant diseases. They also acknowledge the need to address the challenges to be resolved in the implementation of such methods for more efficient plant disease protection. Immitzer et al. [2] in their study, used preliminary Sentinel-2 data and various analysis methods to map vegetation and produce land cover maps. One part of their experiments focused on using the above data to differentiate between crop types and the other on differentiating between seven different deciduous and coniferous tree species for forest management. Their results provide satisfying accuracies for many of their utilized analysis methods. Additionally, Iatrou et al. [3] successfully utilized high resolution satellite data (Worldview-2) to assess changes in the health status of olives with the help of vegetation indices (NDVI, CRI2).

Sentinel-2 imagery has also been used in the case of Hornero et al. [4] to create spectral indices that provide spatio-temporal indications for tracking and mapping damage cause by the pathogen *Xylella fastidiosa*. The ability of satellite data to monitor crop diseases and pests has also been displayed by the work of Yuan et al. [5]. A combination of remote sensing data has been used, with different resolutions each (Worldview 2 and Landsat 8), to calculate a combination of vegetation indices and environmental characteristics. The above managed to accurately reflect the regional spatial distribution of crop diseases and pests.



WP 2 – Pilot versus Idea & Scenario

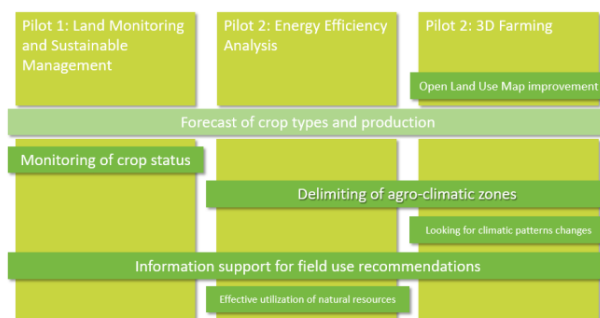


Figure 1. Pilots' relation to scenario implementation.

For this concept, a monitoring system will be designed and implemented based on Sentinel-2 image analysis algorithms in order to monitor the condition of olive crops and detect anomalies in their physiology. Anomalies, as deviations from normal growth, will be further investigated by hyperspectral data and other data sources and attributed to relevant factors such as biotic or abiotic stresses (disease, pests).

The aim of this work is to present the details of the service which will be responsible for the detection of stress levels in olive trees, due to water deficiency caused mostly by pathogens such as *Verticillium dahliae*. The development of the disease detection service aims to provide a holistic management system.

2. MATERIALS & METHODS

2.1 Study Area

Chalkidiki (Figure 2) is located in northern Greece and is an active agricultural zone, with a large amount of the agricultural land used for olive cultivation. A common used variety of olive in the region is the Chalkidiki var., which is one of the most susceptible varieties to biotic and abiotic stresses. In order to achieve high yields, the majority of growers irrigate their fields, which results in favorable growth conditions for the fungal pathogen *Verticillium dahliae* which is responsible for Verticillium Wilt.

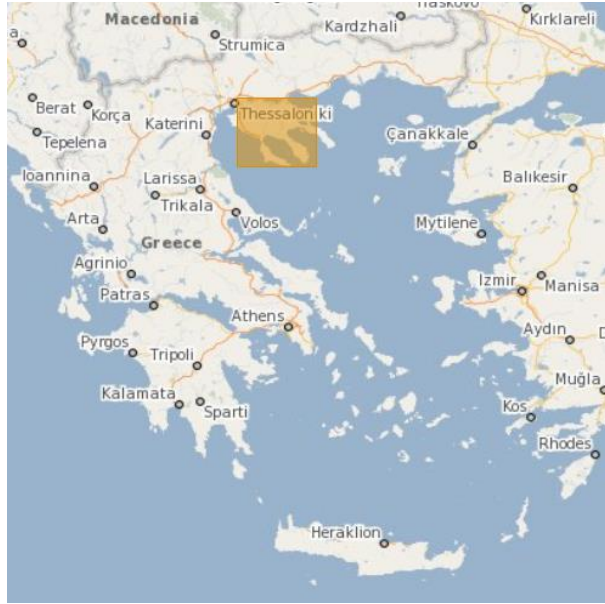


Figure 2. Region of Chalkidiki study area (Northern Greece). Olive cultivations cover a large area of the county. (source: <https://scihub.copernicus.eu/dhus/#/home>)

2.2 Sentinel-2 Data

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 be used for crops and farmland applications.

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.

2.3 Methodology

Carotenoid reflectance index 2 (CRI2) is an index that provides information concerning plant stress levels related to water deprivation [6]. This is due to an increase in carotenoids concentration relatively to chlorophyll concentration decrease in plant tissues, which can consequently be expressed as reflectance differentiations in the electromagnetic spectrum.

A model was built using ArcMap 10.5 tools. To create and test the model (and the resulting script in Python) a sample image (S-2 L2A), including the study area was downloaded from the Copernicus open access hub

(<https://scihub.copernicus.eu/dhus/#/home>), and a subset of the image was processed.

The index is calculated by the following equation:

$$CRI2 = \left(\frac{1}{R_{520}} - \frac{1}{R_{700}} \right)$$

which based on Sentinel-2's band reflectance ranges is better represented by bands 2 and 5:

$$CRI2 = \left(\frac{1}{Band2} - \frac{1}{Band5} \right).$$

In general, the values of the index when applied in green vegetation should have a range of approx. 0 – 20, which is the case when applied to the used data. This index is then applied to the inside of the borders of olive fields and the mean value is calculated.

3. RESULTS

The created model provides a raster file, with the mean values of CRI2 inside the borders of the olive fields. A sample application is presented in Figure 3. High values (reaching 25) are scattered around the study area, but mainly concentrated in the central part, while the lowest values (almost 5) are prominent in the southwest and east. The values are an indication of possible VW infection and can be used as a guide to plan future applications to resolve the issue.

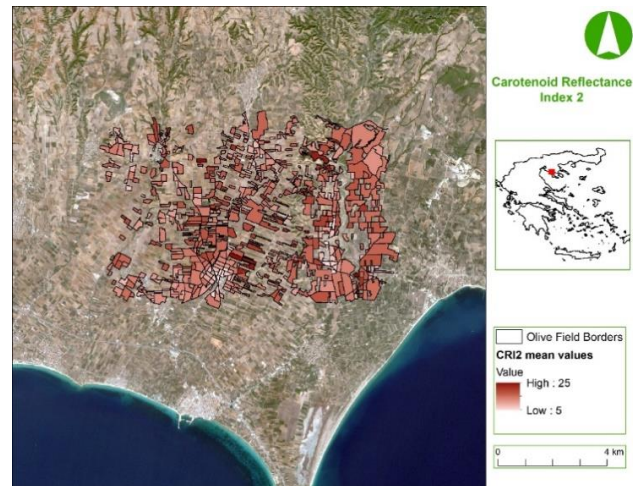


Figure 3. Spectral index showcasing the levels of water stress on olives in Chalkidiki, Greece.

4. DISCUSSION

It can be observed that the level of detail in the CRI2 map is enough to highlight a certain number of fields for further investigation by experts. Also, due to the continuous supply of imagery data from Sentinel-2, a time series of estimations

can be utilized to monitor and assess the progress of stress levels in the fields.

A limitation of this service could be that the apparent stress levels are not specific to a single source, such as a pathogen or abiotic stress, but rather display the deterioration of plant health. Also, in order to properly apply the model, the field borders of olives are a prerequisite to produce field-specific results. There are many occasions that such a database has errors in crop type or, for some cases, it may not exist at all.

Although the model was created using ArcGIS tools in arc.py, it was later modified to work in python using only open source modules for the computations, achieving the same results. This was done, in order to be compatible with the Jupyter notebook environment, which is used for the development of services for mundi.

(<https://mundiwebservices.com/solutions/overview>)

A future aim for this service is to use data from olive fields and provide a more accurate and specific index. Also, further testing of the currently-evolving e-infrastructure with similar vegetation indices models, can enhance its ability to provide cloud processing as an essential need for the end users.

5. CONCLUSIONS

A methodology to utilize Sentinel-2 imagery data to assess olive water stress levels was demonstrated in this work. This was achieved by calculating the CRI2 index, which is used as an indicator of the mean stress levels of a given olive field. A model was created that completes this set of calculations in ArcGIS environment and was modified in python to only utilize open source modules. This makes it compatible with Jupyter Notebook and possible to run in the e-Infrastructure being designed in the EUXDAT project. This kind of service can prove useful for advisors and scientists alike, as it paves the way for a platform which can be used both as an early warning system, as well as to expand into new applications.

6. ACKNOWLEDGEMENTS

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