Doctoral Thesis Title: Remote sensing of fertilisation and irrigation needs in citrus trees.

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Abstract:
The estimation of the nutritional and water content of vegetation is one of the fundamental tasks in agronomic crop management. This task is strongly conditioned by traditional field sampling and laboratory analysis methodologies, which are costly and cover very little crop area.

Multispectral and hyperspectral satellite and drone time series data acquisitions can help to obtain information throughout the phenological cycle, over large crop areas and at a relatively low economic cost.

At present, the few studies that exist focus their efforts on obtaining direct correlations of nutritional and water content with the various vegetation indices. This methodology neglects relevant aspects such as: 1) satellite spatial resolutions, which show a spectral mixture of elements that are not crops and therefore influence the final result and 2) the time of study, since all nutritional elements are dynamic, and therefore high correlation coefficients can be obtained in certain phenological stages and low coefficients in others.

For all these reasons, a series of trials will be designed experimentally on citrus crops, in which field measurements will be taken throughout the phenological cycle in order to develop non-linear regression models and artificial neural networks. These models will be fed with the information obtained by: Multispectral drone, multispectral satellite, synthetic aperture radar (SAR) satellite and hyperspectral satellite.

In order to carry out the exploratory data analysis, it will be necessary to apply data fusion and downscaling techniques to adapt the data before starting the processing and application of the models. It will also be necessary to use segmentation and spectral unmixing techniques to clean and obtain information only on the crop.

Once the data has been cleaned and the machine learning models have been applied, the aim is to obtain geospatial data on nutritional and water content, which will help in the definition of fertilisation and irrigation strategies for the citrus crop.

Available Means:
This project is planned as a series of field trials in which measurements will be taken using various technologies. In addition, foliar samples will be collected from the field for laboratory analysis.

Satellite
Multispectral satellite: Sentinel 2, Landsat 8, Landsat 9
Synthetic Aperture Radar Satellite (SAR): Sentinel 1
Hyperspectral satellite: EnMAP
Thermal satellite: Sentinel 3. SLSTR

Drone
Drone Dji Matrice 300RTK, positioning antenna D-RTK2
Micasense Altum camera: Multispectral sensor: Bands: red, green, blue, red edge, near infrared, thermal.

Field devices
SPAD, a compact meter that provides an indication of the amount of chlorophyll present in the plant leaf.

Proximal soil sensors. FDR capacitive, multi-parametric soil sensors. Volumetric water content, temperature and electrical conductivity measurements.

Atmospheric temperature and humidity sensors. Multiparametric ambient sensors. Relative humidity, temperature and atmospheric pressure measurements.

Laboratory devices
Materials and reagents needed for biochemical analysis of leaf samples. Spectroradiometer, a non-destructive hyperspectral meter, to obtain the spectral signature of the vegetation. Ideally, measurements should be obtained in the solar range.

This project, within the framework of an industrial doctorate, will be carried out in collaboration with the following partners:

1. IIAMA, Land and Atmosphere Remote Sensing (LARS) research group, represented by co-author Luis Guanter.
2. IAM, The citrus and fruit growing research group, represented by the co-tutor Carlos Mesejo.
3. The Agritech company VisualNacert SL, represented by the doctoral student Ferran Fernández.

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