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PHD PROPOSAL

Title : Monitoring the resilience of Mediterranean arboreal heritage by hyperspectral remote sensing

Reference : PHY**-DOTA-**2018**-Numéro d'ordre**

Welcome laboratory at ONERA :

Domain : Physics — ONERA Center : Toulouse

Department : Applied Optics and Techniques (DOTA)

Unit : Optical Properties of Scenes (POS) — Phone : 05 62 25 26 68

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Topic :

The biome "forests, woodlands and Mediterranean scrub" is one of 14 global biomes identified by the WWF (World Wildlife Fund), for which southern European regions represent critical areas due to the impact of climate change (frequency droughts), biodiversity and biomass erosion (loss of endemic species, forest fires, logging), and human activities (expansion of agricultural land, intensive livestock farming, urbanization). Understanding the functioning of this biome and its evolution requires the estimation of parameters describing its biodiversity and its ecosystem services (defined by the Essential Biodiversity Variables [1]). Remote sensing allows monitoring over large areas of these ecosystems. Current work focuses on the characterization of tree species at the stand level (abundance, wealth, distribution). Few of them focus on assessing the functional characteristics of tree species, including their biochemical properties. The latter are related to phenology (leaf pigments including chlorophyll [2]), water stress (water content) and biomass (dry matter content). Thus, they are indicators of the functioning of plants, intervening on their productivity and their ecosystem functions.

Given the specificities of these environments, their observation by remote sensing requires a high spectral richness on the 0.4-2.5 µm optical domain and a spatial resolution adapted to the scales of study: individual, population and ecosystem. Existing Earth observation missions do not meet all of these criteria. Nevertheless, the VENUS multispectral satellite mission at a spatial resolution of 10m with acquisitions in the 0.4-0.9 µm range, will allow to obtain preliminary results pending the projects of new hyperspectral satellite missions under study, including: ENMAP (DLR) and HYSPIRI (NASA) with spatial resolution 30m at the population level, and HYPXIM (CNES) with 8m resolution at population / individual scales.

For one pixel of the image, the estimation of biochemical properties remains very sensitive to the characteristics of Mediterranean forests (low tree cover, soil impact, environmental conditions) and to the intrinsic characteristics of individuals composing the plant cover, including their 3D structure (

crown shape, strong presence of woody elements, low leaf density). For weak spatial resolutions, two new limitations are added: the presence of several individuals and several tree species within the same pixel of the image.

The objective of this thesis is to evaluate the contribution of taking into account the structure of a tree for a given species and the composition of the species in the pixel [3], to improve the estimation of the properties biochemical trees by multi- temporal hyperspectral remote sensing, and allow good monitoring of the state of health of trees by type of species.

The methodology for estimating these biochemical quantities is based on the use of 3D canopy and leaf radiative transfer tools, PROSPECT [4] and DART [5], with a Look-Up Table (LUT) inversion strategy. The simulated spectral reflectance databases above the canopy in the generated LUTs will be compared with the hyperspectral images, to estimate biochemical properties and their spatial mapping. The thesis work will be done on three scales of observation: individual, population and ecosystem. First, we will evaluate at the individual scale, the impact of the structure of an isolated tree on the estimation of these biochemical properties for a given species. The creation of 3D tree models for the use of DART will rely on terrestrial lidar data and simplified geometric shapes. Secondly, the study will continue on the grouping of trees, taking into account mono and multi-species approaches on selected tree plots, and taking the same tree structures defined in the first part. Thirdly, the processing of the entire ecosystem that has been imaged will be considered.

At each step, these methods will be validated with Aviris-Next generation (2m) and Aviris (18m) hyperspectral field and airborne data collected at the study sites between 2013 and 2016 by the University of Davis, California (CSTARS) and NASA [6], to prepare the HYSPIRI mission. This dataset is unique. The areas acquired are woodland savannas in California, mixing pastures and sparse oak and coniferous forests with 1 to 3 endemic tree species, in the context of the drought that began in 2013. Species resilience will be assessed in terms of stress water. The thesis will include a stay in the laboratory CSTARS, as well as participation in an experimental campaign on the sites studied.

Lastly, the method will be applied on a sparsely forested South-European site in the Occitanie region with the collaboration of the CEFE laboratory. For this purpose, an airborne campaign and field measurement is planned during the thesis.

Currently an internship funded by ONERA "Evaluation of the impact of the tree structure on the estimation of the vegetation biochemical properties" should constitute a preliminary study on this topic proposed for this thesis.

[1] Skidmore. Essential biodiversity variables (EBV) and plant functional traits from earth observation and image spectroscopy : powerpoint. 1-13, 2013.
[2] Adeline et al., Spectral sensitivity of radiative transfer inversion for seasonal canopy pigments estimation from AVIRIS data in a woodland savanna ecosystem. Whispers, 8th Workshop on Hyperspectral Image and Signal Processing : Evolution in Remote Sensing, August 2016 (Best paper award).
[3] Adeline et al., The Role of Species, Structure, and Biochemical Traits in the Spatial Distribution of a Woodland Community, AGU Fall meeting, oral, 2015.
[4] Gastellu-Etchegorry et al., Modeling radiative transfer in heterogeneous 3-D vegetation canopies. Remote sensing of environment, 58(2), 131-156, 1996.
[5] Féret et al., PROSPECT-D: Towards modeling leaf optical properties through a complete lifecycle. Remote Sensing of Environment, Volume 193, 204-215, 2017.

[6] Ustin et al., Multiyear Multiseasonal Changes in Leaf and Canopy Traits Measured by AVIRIS over Ecosystems with Different Functional Type Characteristics Through the Progressive California Drought 2013-2015, AGU Fall meeting, oral, 2015.

Collaborations: University of California, Davis, CSTARS (Susan Ustin) ; University of Massachussetts, Boston (Crystal Schaaf) ; Jean-Philippe Gastellu-Etchegorry (CESBIO) ; Jean-Baptiste Féret (IRSTEA-TETIS) ; Jean-Louis Martin (CEFE) ; Clélia Sirami (DYNAFOR)

PROFILE OF CANDIDATE

Formation : Engineering schools optics or physics, Master's degree in physics or applied mathematics

Desired skills : signal / image processing, radiative transfer, scientific programming, 3D modeling, good level in English