Title: Project FOCUS: operational monitoring of disturbances in European forest ecosystems

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Earth Observation data has proven impactful to the development of sustainable forest management practices and conservation policies. At a time of the global trade and climate change, invasive biotic agents can create serious ecological and societal challenges requiring innovative solutions and near-real time monitoring. Detecting and characterizing changes, both in the forest population and in its surrounding environment, is pivotal to securing a timely response to emerging threats posed to forest and plant health.

Project FOCUS (Forest Operational monitoring using Copernicus and UAV hyperSpectral data), funded by the European Commission through the Horizon 2020 programme, aims at introducing new methodologies to innovatively address these challenges. To this end, new field-validated algorithms, based on a novel combination of satellite-derived multispectral data with UAV-derived hyperspectral data, are utilized to help detect changes in the forest population at an earlier stage than what is traditionally possible. Detecting these changes earlier allows for an improved mitigation strategy, and ultimately leads to a more sustainable forest resource and less value lost per year. The novel algorithms are integrated within the forest monitoring service Silvisense (www.silvisense.com), utilizing the latest within machine-learning methodologies to ensure higher quality results while maintaining a cost-efficient production.

A major threat to maritime pine (Pinus pinaster) trees is the infection by Pinewood Nematode (PWN) (*Bursaphelenchus xylophilus*), the biotic agent responsible for Pine Wilt Disease. Native to North America, B. xylophilus requires the simultaneous presence of a vector insect for propagation and suitable host trees (coniferous). The first detection of Pine Wilt Disease (PWD) in Europe happened in 1999, when it was identified in Portugal. The initial cases were followed by the fast spread of this disease nationwide, leading to a decrease of *P. pinaster* area. *P. pinaster* is a very important tree species for the Portuguese economy, through the use of its products and sub-products originated from pine wood. Other susceptible coniferous occur over wide areas in Europe and the potential ecologic and economic losses in the event of a continued expansion of the range of this biotic agent are significant. To contain PWD to Portugal and avoid the propagation of a major threat to European forests, special measures were adopted by the European Union and Portuguese governments. Since then, detections have been made outside of contiguous Portugal, including in the Madeira Islands and Spain, highlighting the serious challenges to containment and eradication efforts.

In PWD external symptoms include a decrease in resin exudation, browning and wilting of needles, and drying of the crown. In this disease, the decline process is very quick and also leads to changes in several parameters even before detection is visually possible.

Plants in stress conditions, produce less chlorophyll during the senescence process, this fact affects the light absorption, and causes the appearance of chloroses in plant tissues, and consequently changes in the reflectance captured from multi- and hyperspectral data. These facts contribute to the use of remote sensing technologies in support of timely detection efforts.

Traditional surveying techniques are ineffective since it is not possible to identify infected trees in dense stands or remote areas from the ground. This limitation has greatly contributed to the unstoppable expansion of the biotic agent. Early detection through remote surveillance is pivotal to ensure European forests outside of the Iberian Peninsula remain PWD-free.

In this work, we present preliminary results of Very High Resolution and Sentinel-2 performance in the detection of the PWD, supported by laboratory and in situ spectroradiometry. An intensive ground survey campaign and multivariate laboratory analysis are also discussed. Healthy and infected trees were selected and monitored across a wilting season in a set of test sites in central Portugal. Several of the previously healthy trees were naturally infected in the course of the season, offering a unique perspective into the spectral and physiological evolution of the disease in the natural environment Monthly sample collection allowed the laboratorial analysis of multiple parameters including the quantification of pigments, phenolic compounds, and nitrates, as well as water content measurements. Correlations between remote, in situ, and laboratorial results were found and are now discussed for the first time.

Preliminary results strongly suggest high resolution satellite-based detection of wilting adult maritime pines is feasible in the context of European forests.

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