Doctoral Thesis Title:
Enhancement of forest structure and point cloud-based fuel models using artificial intelligence methods

Supervisor/s:
Luis Ángel Ruiz Fernández
Pablo Crespo Peremarch

Abstract:
The three-dimensional characterization of forest structure and the precise estimation of fuel variables are essential for the simulation of fire behavior, especially in Mediterranean ecosystems where wildfires represent an increasing threat due to climate change. LiDAR-based remote sensing systems provide detailed three-dimensional information on vegetation, but their operational integration into state-of-the-art fire behavior models remains limited due to the lack of robust methods for extracting variables such as canopy bulk density, fuel load, or live fuel moisture content at the voxel level (Hermosilla et al., 2014). In this context, the research group has developed previous work demonstrating the potential of full-waveform LiDAR for characterizing understory vegetation in Mediterranean forests (Crespo-Peremarch et al., 2018) and for assessing the vertical distribution of forest components using data from different LiDAR systems (Crespo-Peremarch et al., 2020), laying the groundwork for the application of more advanced artificial intelligence techniques, whose state of the art has been recently reviewed by Yun et al. (2024).

This thesis is framed within two of the objectives of the AIM Fire project (PID2024-158591OB-I00): the compilation of a comprehensive dataset based on point clouds, and the development of forest structure variable models based on AI techniques. To achieve this, the main tasks will consist of the acquisition, compilation, and curation of datasets at different scales, both local and international, including field data, point clouds from terrestrial, mobile, airborne, and satellite LiDAR systems, as well as spectral data from UAV and satellite sensors; the generation of synthetic data through data augmentation techniques in point clouds, creating semi-real scenarios that allow for the training of more robust and generalizable models at both local and global scales; and the development of models based on deep learning techniques adapted to point cloud processing for the estimation of forest structure and combustibility variables (biomass, canopy bulk density, canopy base height) at plot and individual tree levels, following recent approaches such as the semantic segmentation of photogrammetric point clouds for the estimation of species-specific biomass (Carbonell-Rivera et al., 2026).

The results of this thesis will advance the operational integration of LiDAR data and artificial intelligence techniques into new fire behavior models, contributing to improved forest management and fire prevention in Mediterranean environments.

Available Means:

The research will be conducted within the CGAT-UPV group, with access to computing and office infrastructure at the Vera campus, and to field equipment provided by the project: terrestrial laser scanner (TLS), mobile laser scanner (MLS), UAVs equipped with RGB, multispectral and LiDAR sensors (ULS), and forest inventory tools. Field campaigns will be carried out in permanent plots in the Sierra de Espadán and Sierra Calderona.

Open-access data (Global LFMC, Copernicus, NASA) and data from the Generalitat Valenciana and VAERSA will be available. Processing will be supported by Python (PyTorch, TensorFlow, Keras), point cloud libraries (PDAL, Open3D, laspy), GIS software (QGIS, SNAP), and CloudCompare. The project benefits from collaboration with Dr. Marta Yebra (Australian National University) and Prof. Richard Fournier (Université de Sherbrooke), and is funded by the AIM Fire project (PID2024-158591OB-I00).

References:

Carbonell-Rivera, J. P., Ruiz, L. Á., Estornell, J., & Torralba, J. (2026). Species-specific aboveground biomass estimation using semantic segmentation of UAV photogrammetric point clouds. Science of Remote Sensing, 13, 100421. https://doi.org/10.1016/j.srs.2026.100421

Crespo-Peremarch, P., Tompalski, P., Coops, N., & Ruiz, L. Á. (2018). Characterizing understory vegetation in Mediterranean forests using full-waveform airborne laser scanning data. Remote Sensing of Environment, 217, 400–413. https://doi.org/10.1016/j.rse.2018.08.033

Crespo-Peremarch, P., Fournier, R. A., Nguyen, V.-T., van Lier, O. R., & Ruiz, L. Á. (2020). A comparative assessment of the vertical distribution of forest components using full-waveform airborne, discrete airborne and discrete terrestrial laser scanning data. Forest Ecology and Management, 473, 118268. https://doi.org/10.1016/j.foreco.2020.118268

Hermosilla, T., Ruiz, L. A., Kazakova, A., Coops, N. C., & Moskal, L. M. (2014). Estimation of forest structure and canopy fuel parameters from small-footprint full-waveform LiDAR data. International Journal of Wildland Fire, 23(2), 224–233.

Yun, T., Li, J., Ma, L., Zhou, J., Wang, R., Eichhorn, M. P., & Zhang, H. (2024). Status, advancements and prospects of deep learning methods applied in forest studies. International Journal of Applied Earth Observation and Geoinformation, 130, 103816.