

SIMULATING LIDAR TO UNDERSTAND FIRE EFFECTS

Integrating Radiative Transfer Models and 3D forest reconstruction for post-fire analysis

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INTRODUCTION



Forests are vital components of the global carbon cycle, acting as both carbon sinks and sources depending on their health and disturbance levels (Vahedifard et al., 2024). Monitoring changes in forest biomass and structure, particularly in the context of increasing wildfire intensity and frequency (Ruffault et al., 2020), is necessary for understanding ecosystem dynamics and managing resources (Bispo et al., 2016; Haemaelaenen et al., 2024).

Traditional field-based methods for biomass estimation, while reliable, are labor-intensive and often limited in scope. Terrestrial LiDAR systems (TLS), offer a fast, non-destructive, high-resolution alternative for capturing forest structure and estimating aboveground biomass (AGB) (Calders et al., 2020; Newnham et al., 2015; Delagrangue et al., 2014; Hackenberg et al., 2015).

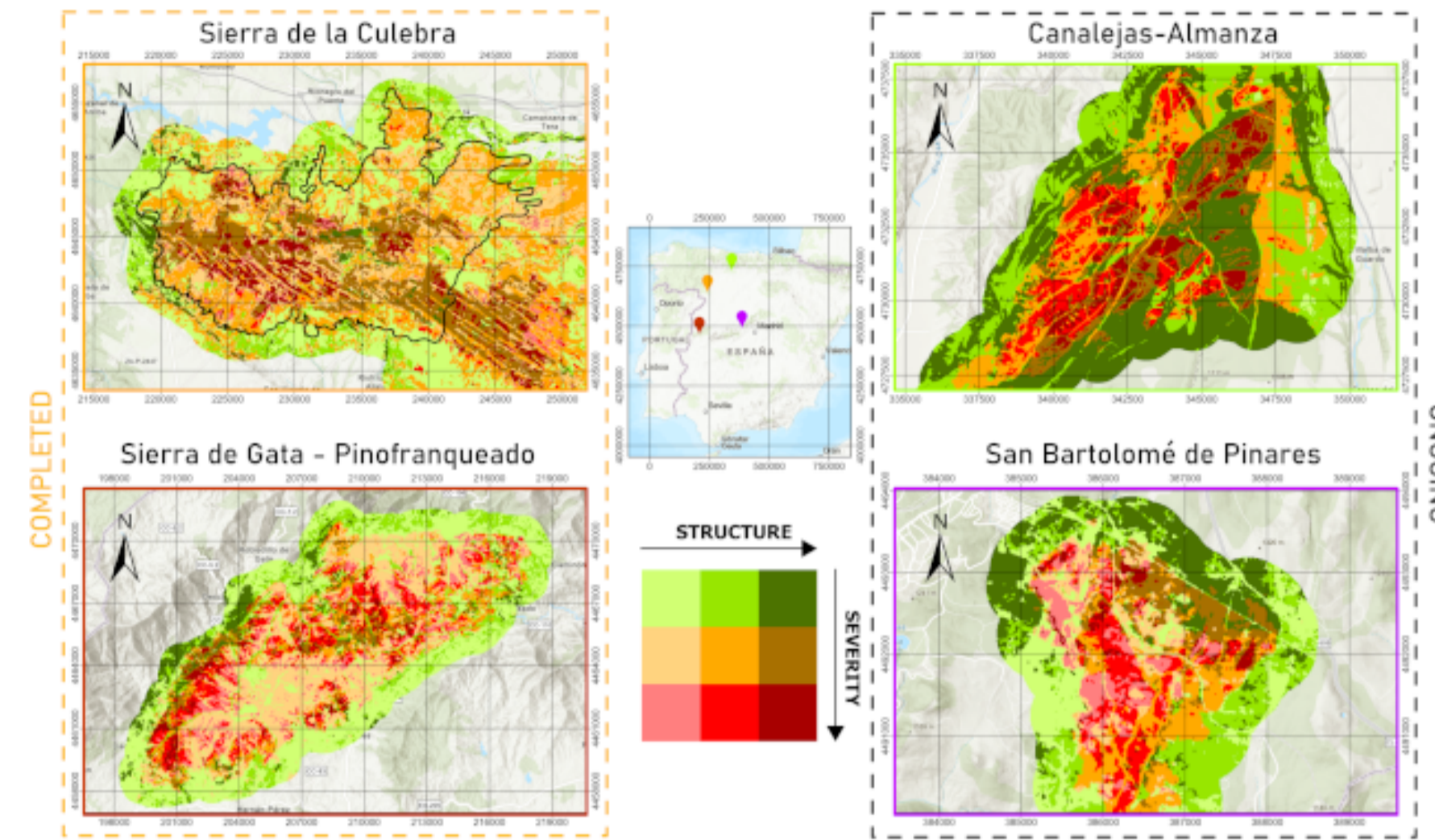
Radiative transfer models enabled the simulation of laser pulse interactions with forest elements across different fire severities. The

models used account for the scatter, absorption and reflectance of the laser pulse, at the same wavelength of the validated data, 1610nm. The simulation results of biomass consumption can further be used to develop combustion completeness models, which may incorporate more operationally accessible data, such as optical remote sensing, to assess carbon emissions effectively.

The objectives of this study were to:

- Reconstruct realistic 3D forest and vegetation models from field and LiDAR data.
- Simulate LiDAR acquisitions before and after fire using Helios++ Radiative Transfer Model.

STUDY SITES - DATA



Our study sites, located in Peninsular Spain cover:

- Sierra de la Culebra, Zamora.
- Sierra de Gata, Cáceres.
- San Bartolomé de Pinares, Ávila.
- Canalejas-Almanza, León.

From these field campaigns, the following data is expected to be extracted: At least 85 plots, ranging from 12 m to 17 m diameter. In all campaigns DBH was measured in all trees, while height was measured in 25% of the trees using a Vertex V instrument. On 37 of those plots, tree location was registered using a Reach RS2 GPS system, which resulted in a total of 807 tree-level validated individuals.

Depending on the site, the following data was also acquired:



DBH and height was acquired on all campaigns as structural and AGB validation metrics.

Tree position was recorded on Sierra de Gata, San Bartolomé and Canalejas, with a maximum error of 20 centimeters.

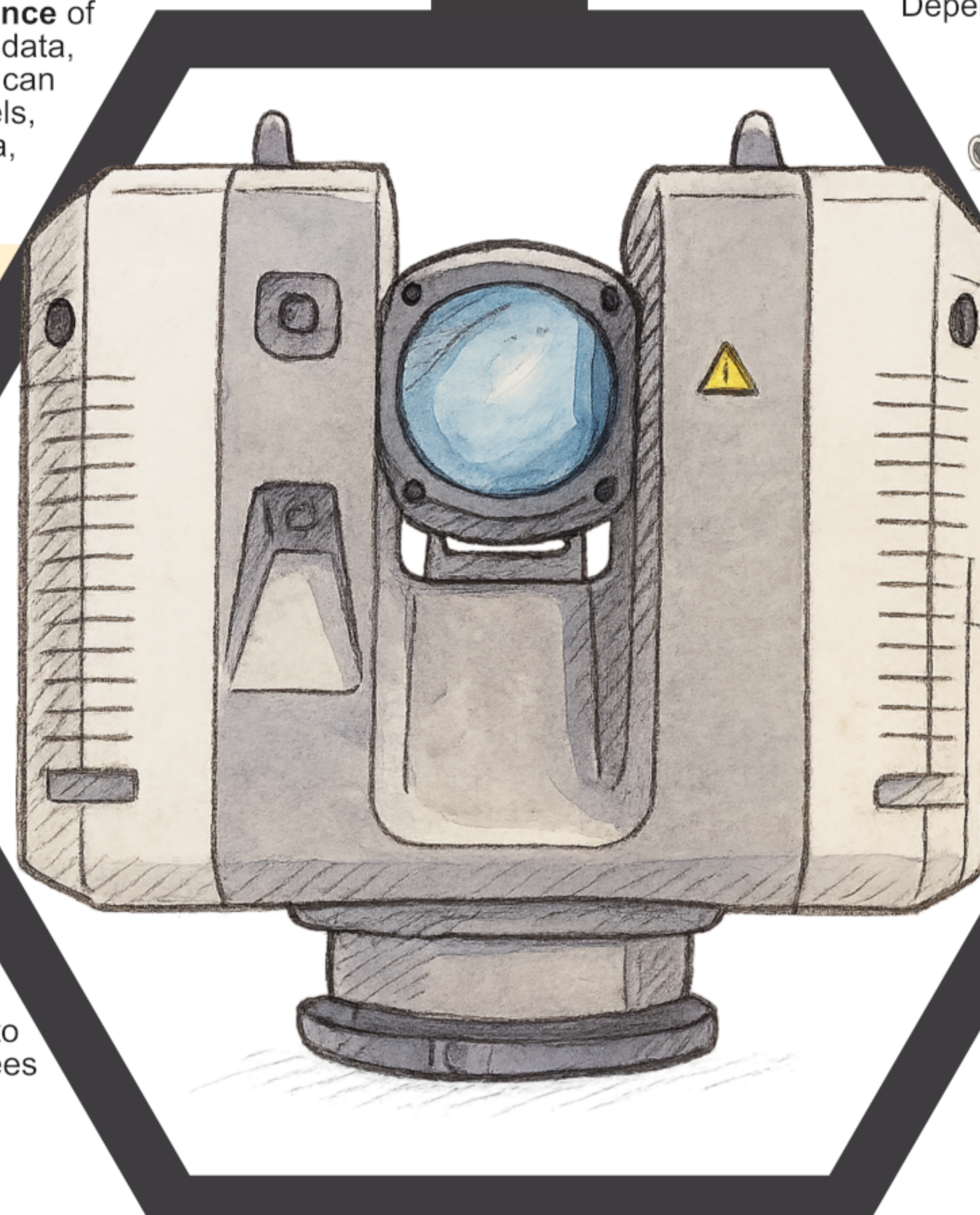
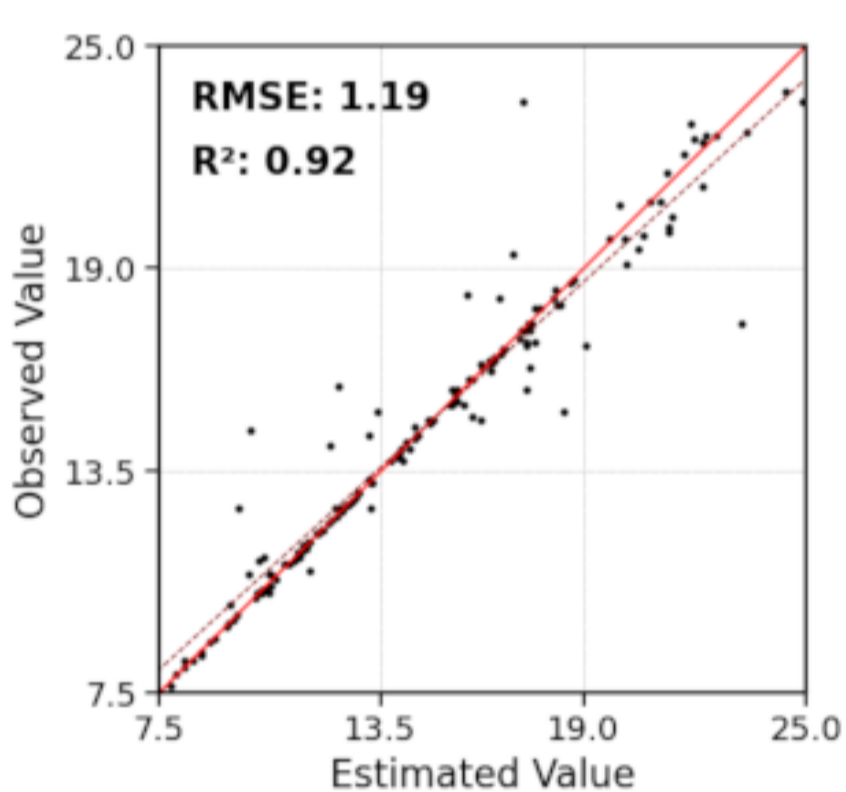


TLS scanning was acquired on Sierra de la Culebra and Gata campaigns.

UAV LiDAR scanning was acquired on San Bartolomé and Canalejas campaigns.

TREE METRICS

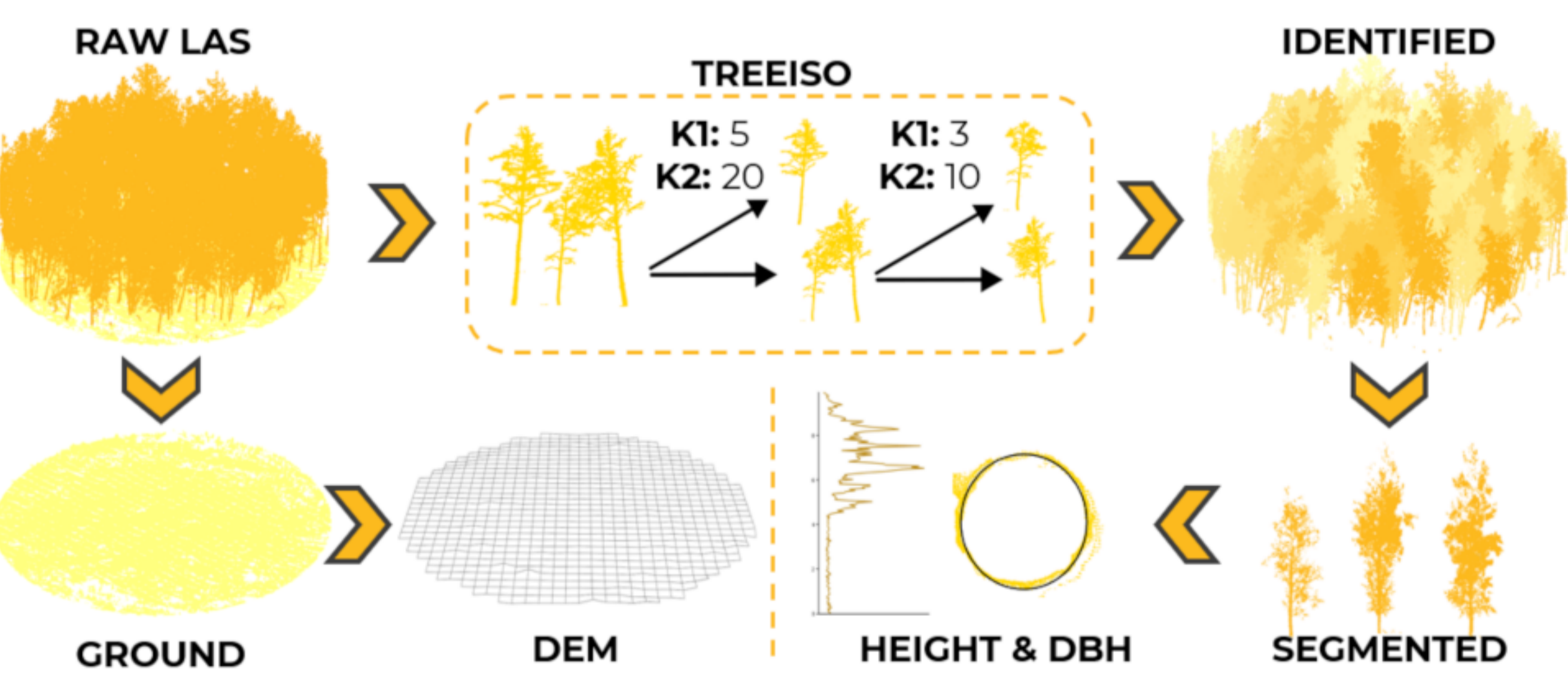
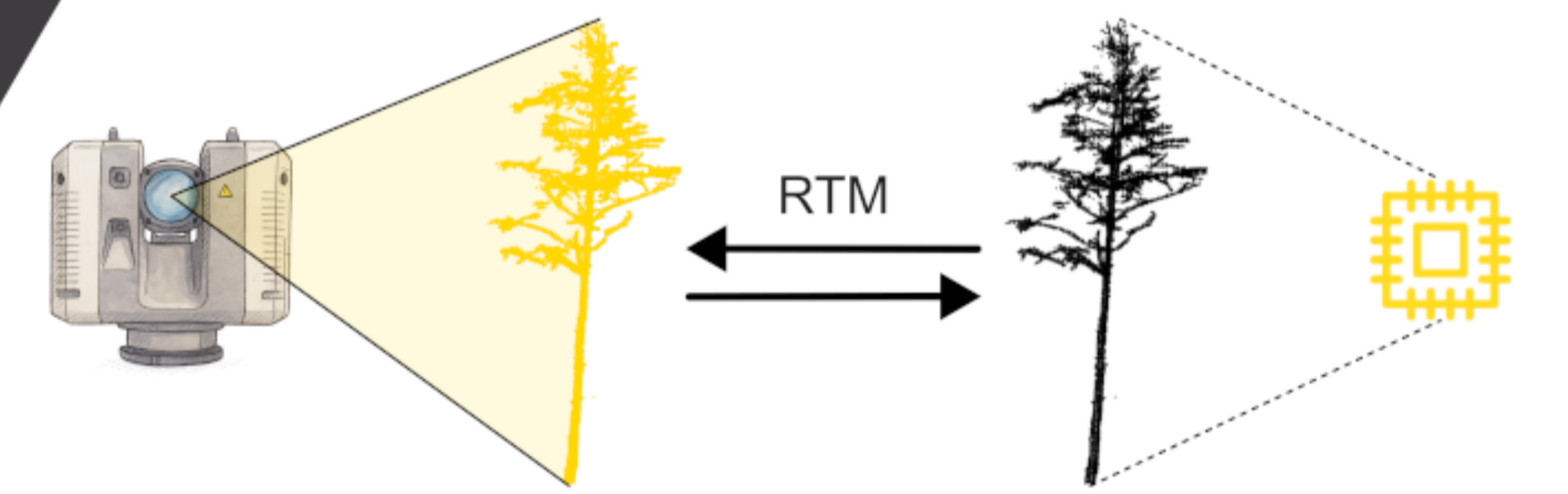
Preprocessing methodology is based on established steps; classification, normalization and noise filtering (SOR). Trees are then identified and segmented with an iterative implementation of Treeiso, which requires manual input, but allows for an increased tree extraction capability. Model trees are then selected to extract metrics which are then used to generate 3D object trees. Model trees have very high agreement with validation data ($R^2 > 0.9$).



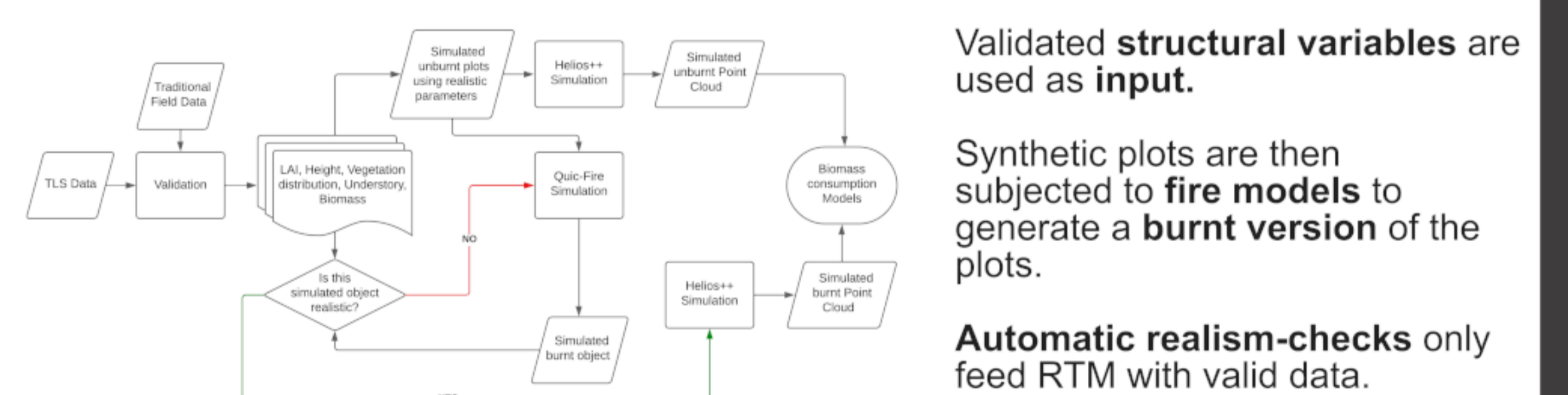
R.T. MODELS

RTM modelled from validated realistic structural variables allows to create and control:

- Hundreds of plots with varying initial settings.
- Apply fluid dynamics fire models, to subject each plot to multiple fire intensities and conditions.

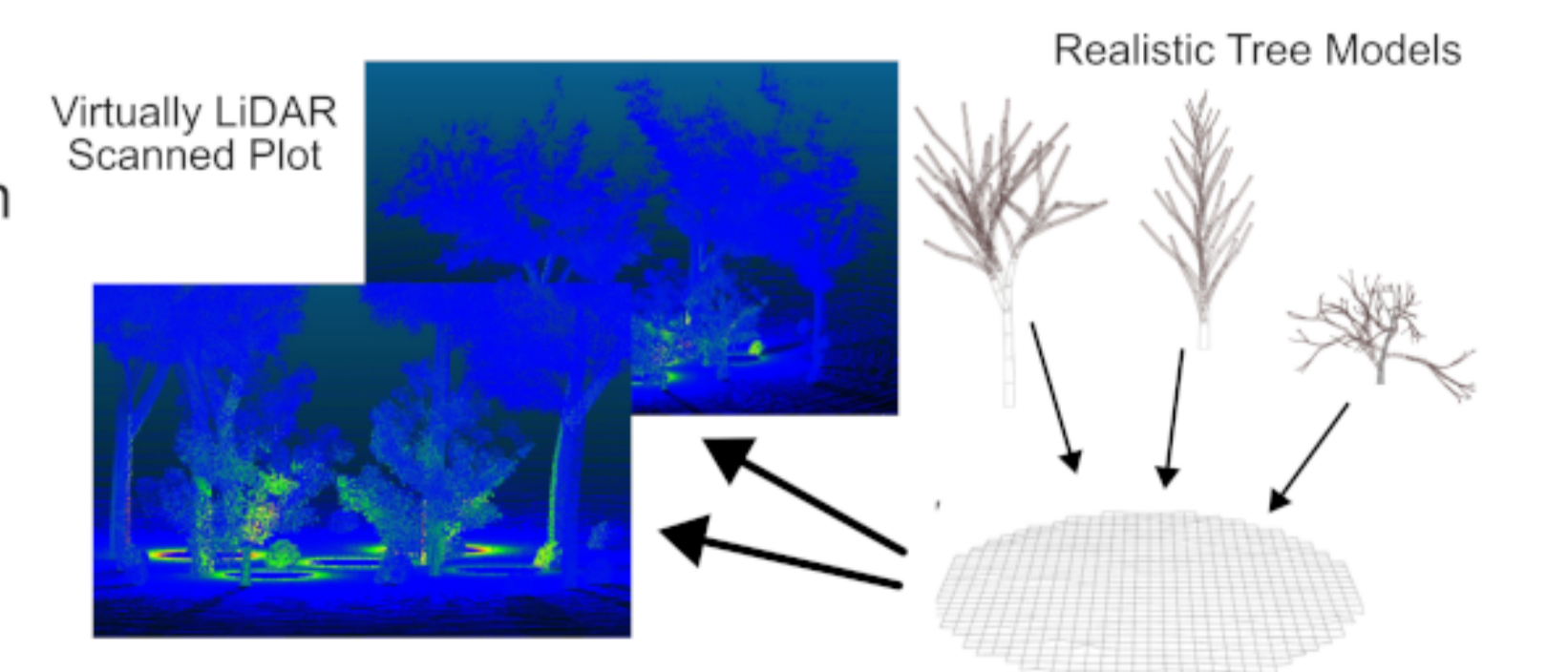


Tree level (point cloud and QSM) and plot level (point cloud and dem) metrics are used to generate tree models. These metrics are mainly: 1) structural variables; 2) crown and branching metrics; 3) foliage metrics; 4) plot distribution; 5) tree population metrics; 6) terrain metrics.



The radiative transfer model used is Helios++, an open-source simulation framework developed in 3DGeo, Heidelberg University.

It generates discrete and full wave-form LiDAR simulations from a static or dynamic sensor.



ACKNOWLEDGMENTS AND REFERENCES

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