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PRECISIONPOP: a multi-scale monitoring system for poplar plantations integrating field, aerial and satellite remote sensing

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Poplar (*Populus* spp.) plantations are globally widespread in the Northern Hemisphere, and provide a wide range of benefits and products, including timber, carbon sequestration and phytoremediation. Because of poplar specific features (fast growth, short rotation) the information needs require frequent updates, which exceed the traditional scope of National Forest Inventories, implying the need for *ad-hoc* monitoring solutions.

Here we presented a regional-level multi-scale monitoring system developed for poplar plantations, which is based on the integration of different remotely-sensed informations at different spatial scales, developed in Lombardy (Northern Italy) region. The system is based on three levels of information: 1) At plot scale, terrestrial laser scanning (TLS) was used to develop non-destructive tree stem volume allometries in calibration sites; the produced allometries were then used to estimate plot-level stand parameters from field inventory; additional canopy structure attributes were derived using field digital cover photography. 2) At farm level, unmanned aerial vehicles (UAVs) equipped with multispectral sensors were used to upscale results obtained from field data. 3) Finally, both field and unmanned aerial estimates were used to calibrate a regional-scale supervised continuous monitoring system based on multispectral Sentinel-2 imagery, which was implemented and updated in a Google Earth Engine platform.

The combined use of multi-scale information allowed an effective management and monitoring of poplar plantations. From a top-down perspective, the continuous satellite monitoring system allowed the detection of early warning poplar stress, which are suitable for variable rate irrigation and fertilizing scheduling. From a bottom-up perspective, the spatially explicit nature of TLS measurements allows better integration with remotely sensed data, enabling a multiscale assessment of poplar plantation structure with different levels of detail, enhancing conventional tree inventories, and supporting effective management strategies. Finally, use of UAV is key in poplar plantations as their spatial resolution is suited for calibrating metrics from coarser remotely-sensed products, reducing or avoiding the need of ground measurements, with a

significant reduction of time and costs.