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Dataset paper

Collection: "Precision tools to support poplar plantation Forestry"

Dataset of tree inventory and canopy structure in poplar plantations in Northern Italy

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ABSTRACT The dataset reports data collected in 38 square (50 x 50m) 0.25 ha plots representative of poplar plantations in Lombardy Region (Northern Italy), which were used to calibrate optical information derived from unmanned aerial vehicle (UAV) and satellite (Sentinel-2) sensors. In each plot, the diameter at breast height was measured using a caliper; height, stem and crown volume of each tree were then derived from diameter using allometric equations developed in an independent study. Additional canopy attributes (foliage and crown cover, crown porosity, leaf area index) were derived in each plot from 12-20 optical images collected using digital cover photography (DCP). The collected data allows characterizing the assessment of structure of these plantations, along with their variation over the rotation time. Canopy and crown data also enable the evaluation of optimal rotation and tree spacing, as well as the relationship between stand and canopy structure. The raw datasets consist of 2,591 records (trees) associated with inventory measurements and 616 records (images) associated with optical canopy measurements. An R code was also provided to calculate plot-level attributes from raw data. Dataset and associated metadata are freely available at http://dx.doi.org/10.17632/ycr7w5pvkt.1.

KEYWORDS: leaf area index, hybrid I-214 poplar, precision forestry, crown volume, stem volume.

Introduction

Poplar plantations provide a wide range of wood products and are also used for phytoremediation and carbon sequestration. Because of their specific features (fast growth rate and short rotation, dependency on the wood price market), poplar plantations are characterized by large inter-annual fluctuation in their planted area, which required frequent update of information about their geographical distribution and wood supply (Corona et al. 2020).

Remotely-sensed information provides a unique way to assess poplar plantations attributes at spatially-extensive scale while allowing their repeated and frequent monitoring (Marcelli et al. 2020). While recent satellite sensors like Sentinel-2 (S2) have the advantage of high resolution (10 m) and quick revisit time (5-7 days), which makes them highly suitable for larger-scale applications, recent advances in unmanned aerial vehicles (UAV), digital photography technologies and structure from motion (SFM) photogrammetry holds great potential for finer assessment of poplar structure at tree to plantation level.

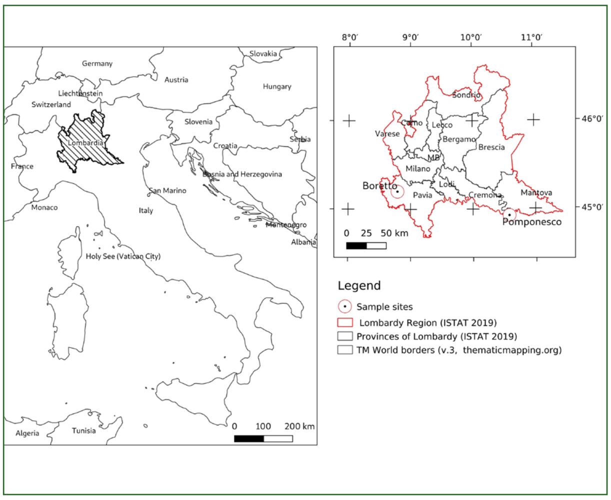
The dataset reported here compiled data from 38 square 0.25 ha plots representative of poplar plantations in Lombardy Region (Northern Italy). These data were collected in the framework of the Research Project PRECISIONPOP (https://precisionpop.net), funded by the Lombardy Region, aimed at exploiting different remotely-sensed data to support poplar plantation forestry at different spatial scales. The dataset served as ground truth data, which has been used to calibrate optical information derived from unmanned aerial vehicle (UAV) and satellite (Sentinel-2) sensors employed in the Research Project.

Material and methods

Study area

Data were collected in two poplar plantation farms located in Lombardy Region, Northern Italy (Fig. 1). Data at Pomponesco (MN) site were collected in 2019 in a previous study (Chianucci et al. 2021) while data at Cergnago (PV) were collected in the current study in 2020. A total of 38 square plots, each 2,500 m^2 ha in size, were selected in poplar plantations, whose age ranged between 4 to 12 years old. About 71% of the sampled plantations consists of 'I-214' (*Populus* × *americana*) hybrid clone, the most diffuse one used in Italy, while other clones sampled comprised Boccolari (11%), Beauprè (8%) Polargo (5%) and others (5%). The tree spacing varied between 36 m^2 (6x6 m) to 49 m^2 (7x7 m).

Figure 1 - Map of the sample sites.



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Tree inventory data

In each plot, the diameter at breast height (D) was measured using a caliper; tree height (H) was then derived from D using allometric equations derived in an independent study (Chianucci et al. 2020) from model tree selected and measured in a sub-set of trees sampled in the same plantations. The height models, which were separated for diameter classes, took the following formulas (Eq. 1):

$$H = 1.3 + \frac{22.51}{1+231.82 \cdot exp(-0.264D)}, \text{ for } D \geq 24 \text{ cm} \quad (1a)$$

$$H = 1.3 + \frac{12.49}{1+33.32 \cdot exp(-0.420D)}, \text{ for } D < 24 \text{ cm} \quad (1b)$$

Similarly, stem volume (Vst) and crown volume (Vcr) were derived for each tree from allometric models, separated for diameter classes, derived in the same study (Chianucci et al. 2020):

$V_{st}=exp(-7.40)D^{2.02}$, for D≥ 24 cm, (2a),

$V_{st}=exp(-8.13)D^{2.26}$, for D< 24 cm, (2b),

$V_{cr}=exp(-4.10)D^{2.87}$, for D≥ 24 cm, (3a),

$V_{cr}=exp(-0.91)D^{1.90}$, for D< 24 cm, (3b).

Tree spacing (Tree.sp; m^2) was also recorded in the dataset.

Canopy structure data

In each plot, 12-20 digital cover photography (DCP; Fig. 2) images were collected along a grid of sampling points, using a Nikon D90 Digital Single-Lens Reflex (DSLR) camera equipped with a fixed Nikkor 50 mm 1:1.8 D lens, which yielded about 30° field of view (FOV). All cover images were acquired and processed using the protocol by Chianucci (2020b) as following described.

Figure 2 - An example of a digital cover photography (DCP) image of a poplar plantation. For explanation of canopy attributes derived from DCP, see Chianucci et al. 2021.

The images were acquired in raw (Nikon's NEF) format. The camera was set in aperture-priority mode, with the aperture set to F10.0; exposure was set to underexpose the image by one stop (REV -1). After collection, raw DCP images were first pre-processed using the 'RAW2JPG' toolbox (Macfarlane et al. 2014). The NEF format was converted to 12-bit linear (demosaiced), uncompressed portable gray map (pgm) format using 'dcraw' (Coffin 2011). The blue channel was selected, and a linear contrast stretch was applied using the 'imadjust' function of the 'Image Processing Toolbox' in MATLAB (MathWorks Inc., USA). Images were then converted to 8 bits and saved as JPG files. A gamma adjustment was also applied to the raw images (Macfarlane et al. 2014).

DCP images were then thresholded using the two-corner method of Macfarlane (2011). This method first identifies the unambiguous sky and canopy peaks of the image histogram and then detects the point of maximum curvature to the right and left histogram peaks. Mixed pixels located between the peaks were then classified with a dual threshold. Once classified, a gap size approach was used to further separate large between-crowns gap from total gap fraction (GF). Gaps larger than 1.3% of the image area were classified as between-crowns gaps as proposed by Macfarlane et al. (2007). Two distinct canopy cover estimates were then derived from classified gap size. Crown cover (CC; sensu Macfarlane et al. 2007) was defined as the complement of large between-crowns gap, including within-crown gap as part of the canopy:

$$CC = 1 - \frac{N_L}{N_T} \quad (4)$$

where N_T is the total number of pixels and N_L is the total number of pixels located in the large gaps. Conversely, foliage cover (FC) was defined as the complement of total gap fraction (including within-crown and between-crowns gaps):

$$FC=1-GF \quad (5)$$

where GF is the total gap fraction. Crown porosity (CP) was also calculated as the ratio of gaps within-crown:

$$CP = 1 - \frac{FC}{CC} \quad (6)$$

Leaf area index (LAI), adjusted for clumping, was also calculated as:

$$LAI = -CC\frac{\ln(CP)}{k} \quad (7)$$

Where k was assumed as 0.85 (planophile leaf distribution) based on visual observations. The two-corner classification method and gap size classification were implemented using the 'DCP 3.15' software (Macfarlane et al. 2014).

Dataset content

The dataset is available at the following reference and doi: Chianucci 2020a. Dataset of tree inventory and canopy structure in poplar plantations in Northern Italy. Mendely data, v.1 [Dataset], http://dx.doi.org/10.17632/ycr7w5pvkt.1. The dataset is comprised of four files, consisting of two dataset tables for respectively tree inventory data ("tree_inventory_dataset.csv") and canopy data ("dcp_dataset.csv"), a descriptive metadata table ("metadata_description.xlsx") and a R script, which were available from the repository URL. The tree inventory dataset consists of 2,591 records associated with the trees measured in the 38 plots. The canopy dataset consists of 616 records associated with the images collected and processed in the 38 plots. An R script ("script.R") is also available to calculate plot-level stand and canopy statistics from raw data. All the data are provided without georeferenced information; georeferenced data are however available from the authors upon request.

Reuse potential and limits

The dataset allows characterizing the structure of poplar plantations, along with its variation over the rotation time (which is typically 10 years). While diameter and stem volume allowed the assessment of structure, wood supply and log assortments of these plantations, crown volume also allows the evaluation of different spacing schemes in poplar (Chianucci et al. 2020).

Leaf area index and other canopy attributes are useful for multiple purposes, including *i)* evaluating the relationship between stand and canopy structure; *ii)* monitoring stand vitality and productivity; *iii*) parametrizing ecological and processed-based canopy photosynthesis models; *iv*) calibrating and validating remotely-sensed information. The plot size is suitable for comparison with high to medium resolution aerial and satellite products and unmanned aerial vehicles (Chianucci et al. 2016).

As the information collected here are related to pure 'even-aged' plantations, no information on mixed polycyclic plantations is available from the dataset. However, information from crown volume and canopy structure may help elucidating different spacing requirement in poplar, which could be used for designing also mixed polycyclic plantations.

In addition, while most of the information collected in this dataset are related to the 'I214' hybrid poplar, which represent the predominantly used clone in Italy, we planned to include new measurements in other plantation plots, which are most representative of other poplar clones, which will be available in future field campaigns and new version of the dataset.

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Annex

Report on data description and analysis.

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