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Estimate of canopy bulk density through clip-on fisheye lens: an easy fix to forest fires simulations

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1. Introduction

Forest fires hot topic of land management

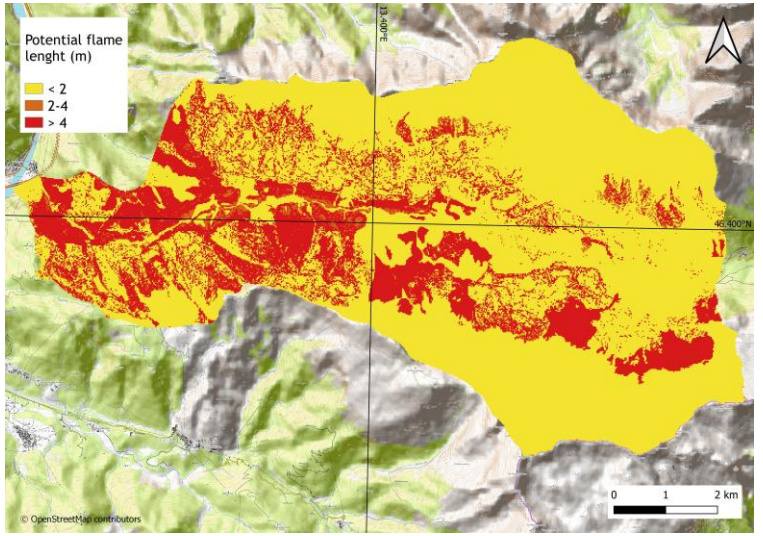
Fire simulators to face fire risk → FLAMMAP

For land managers, firefighting bodies, etc.

Some input data from remote sensing (stand h, land cover, …)

Fuel data often difficult to get → one-size-fits-all values

e.g., **Canopy Bulk Density (CBD)**



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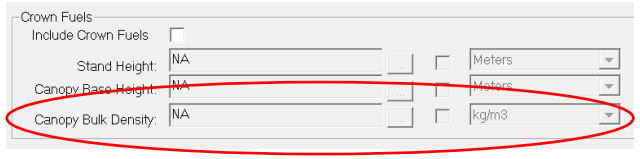
1. Introduction

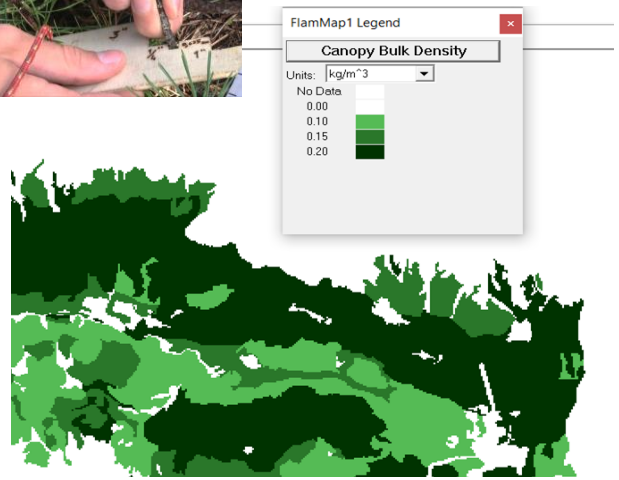


Canopy Bulk Density (CBD)

→ ***Mass of burnable fuel per volume unit of forest canopy (i.e., set of trees crowns)***

- Destructive sampling for measurement
- Changing with forest structure, species, phenology, age, …
- Necessary for crown-to-crown fire spread simulation

… often inputted as constant



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1. Introduction

Indirect methods to estimate CBD

Keane et al. 2005*, 6 methods

Fisheye lens to take hemispherical photos

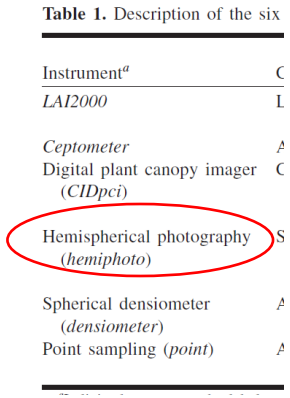

Table 1. Description of the six

Instrument[a]	C
LAI2000	L
Ceptometer	A
Digital plant canopy imager (*CIDpci*)	C
Hemispherical photography (*hemiphoto*)	S
Spherical densiometer (*densiometer*)	A
Point sampling (*point*)	A

Part of table from Keane et al. 2005*

*Keane, R. E., Reinhardt, E. D., Scott, J., Gray, K., & Reardon, J. (2005). Estimating forest canopy bulk density using six indirect methods. Canadian Journal of forest research, 35(3), 724-739.

Hypothesis

Can we estimate Canopy Bulk Density from a smartphone clip-on fisheye lens and free software?

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2. Materials and methods

Clip-on fisheye lens + smartphone

Custom-made stand (levelled, h=2 m)

GNSS receiver


Pinus nigra


Pinus pinaster

3 sampling areas in NE Italy

Total 148 photos with fisheye:

- 90 in two *Pinus pinaster* stands (58+32)
- 58 in a *Pinus nigra* stand

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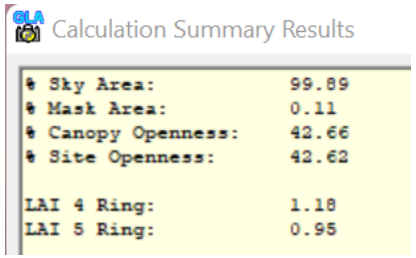
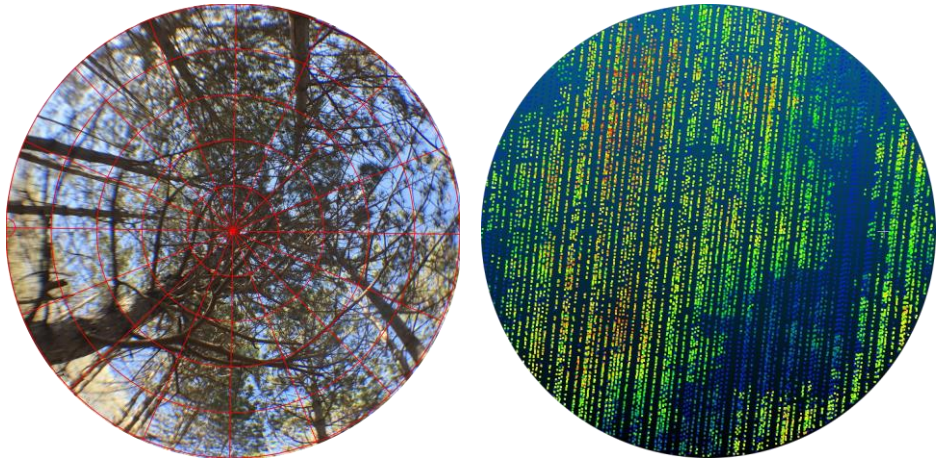
2. Materials and methods

Gap Light Analyser for photos processing

CBD from Keane et al. 2005* equations → mostly based on $LAI^{45^{\circ}}$ or **gap fraction**

Literature values as control *(gap fraction = percent of sky visible from beneath the forest canopy)*





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2. Materials and methods

LiDAR on same plots to **spatialise**

→ 2 batches:

- *P. nigra* ca. 16 pts/m^2, flight 2017-2020
- *P. pinaster* ca. 1 pt/m^2, flight 2012

FUSION and LASTools via QGIS plugins for analyses

Linear regression between fisheye gap fraction (y) and LiDAR canopy cover (x) using R

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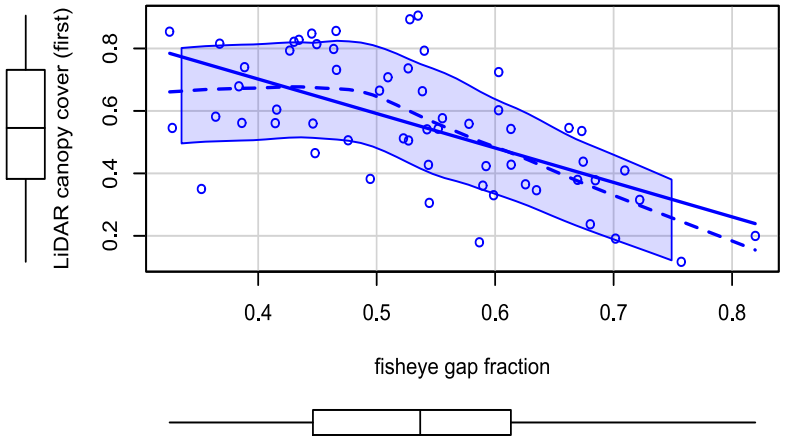
3. Results and discussion

CBD from fisheye pics and equations

Equation n.	*Pinus nigra*	*Pinus pinaster*
1 («Hemiphoto E»)	0.11	-0.13
2 («Hemiphoto A»)	0.07	0.11
3 («Hemiphoto E» + ancillary data)	0.16	0.02

based on canopy gap fraction

Regression gap fraction ~ LiDAR canopy cover (first returns)



Only *P. nigra* significant, R^2adj = 0.38

Literature values*: 0.06-0.21 kg/m^3

* Scott, Joe H.; Reinhardt, Elizabeth D. 2001. **Assessing crown fire potential by linking models of surface and crown fire behavior.** Res. Pap. RMRS-RP-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

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3. Results and discussion

- Results from fisheye photographs CBD **in line with literature**
- If recent and high-quality **LiDAR** data, possible to **spatialise** CBD
- For *P. pinaster* no significant relation with LiDAR: possibly old LiDAR, forest cuts, …

Caveats and possible improvements

- Equations used “as are”
- Validate with ground truth if possible (forest thinnings)
- Account for forest structure

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4. Conclusions

- Methodology simple and cheap enough to replicate with land managers, etc.
- Coupling with LiDAR satisfactory if “good” data available
- Spatialised CBD values a better input layer for simulators than fixed values

Next steps

→ Increase sample size

→ Test simulator with new data

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Thank you for your attention