Modeling the horizontal distribution of tree crown biomass using terrestrial laser scanning: a new pathway for advancing the accuracy of forest biomass or carbon estimates

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Highlights

- A new model, ***Horizontal Biomass Distributions (HBD)***, developed to depict the spatial distribution of tree crown biomass.
- The model developed assuming isotropy, circular crown projection, and upright stems.
- Certain variability in *HBD* was observed between tree species groups.

Introduction

- Conventionally, tree biomass assigned exclusively to stem position; which does not hold in reality.
- Crown biomass rather spatially distributed over the area defined by the crown projection.
- The need for complete biomass estimates (in remote sensing methods); while inventory approaches are still incomplete!
- *HBD* model [**1**], for describing biomass continuously across the crown projection area (**Fig. 1**).

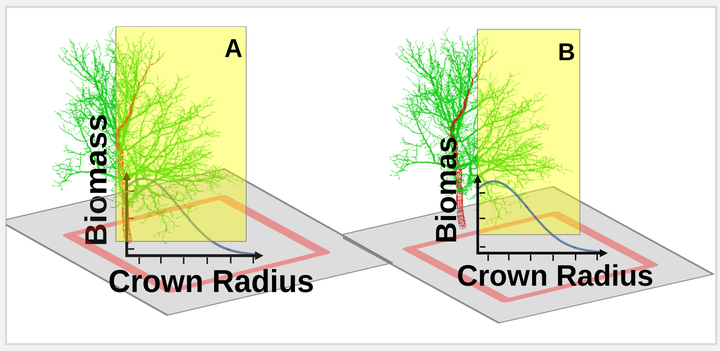


Fig. 1. Illustration of *HBD;* biomass depicted continuously. Assume inventory plots (image pixels) (red-box) – biomass is the portion crown biomass within the area defined by crown projection (**A** and **B**).

Methods

- Terrestrial laser scanning (TLS) data for 33 urban trees of 8 species (Göttingen, Germany).
- Quantitative structural modeling (QSM) for biomass proxies.
- Clustering stem and crown parts (**Fig. 2**).

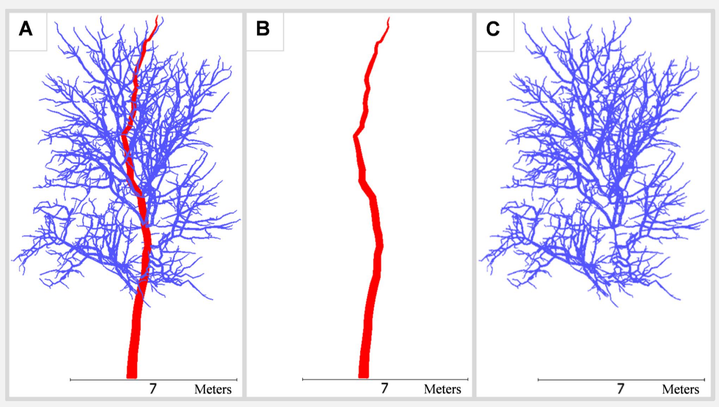
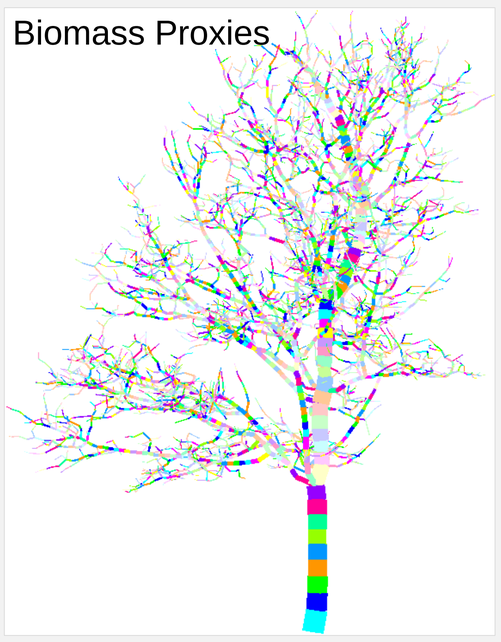


Fig. 2. Process of clustering stem (red) and crown (blue) components. Vertical projection area of the stem was assumed to be insignificant.

Methods

- Biomass proxies ≈20cm branch point cross-sections (**Fig. 3**).
- Then biomass of branch cross-sections projected on horizontal plane (**Fig. 3A**).
- Empirical biomass extraction continuously from 20cm circular bins (**Fig. 3B, C**).
- Assumptions for *HBD* modeling process: **(1)** Perfectly upright stems, **(2)** Circular crown projection, **(3)** Isotropic biomass distribution radially around stem axis.



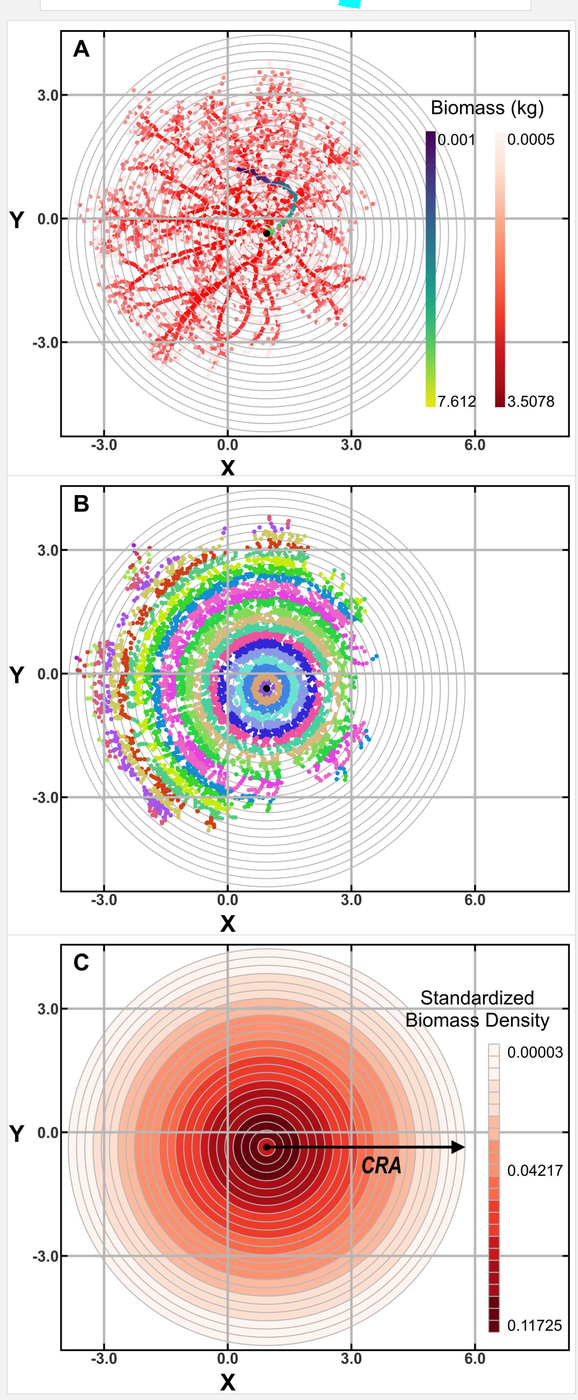


Fig. 3. Top: Biomass of ≈20cm branch point cross-sections. **A, B, C:** Projecting biomass values onto the horizontal plane and subsequent extraction for empirical modeling process.

Results

- Segmented polynomial regression model - *HBD* descriptive empirical model **[1]**.
- Some variability of *HBD* observed between tree species groups (**Fig. 4**).
- The variability principally with varying crown architectures and irregular vertical orientation of tree stems.

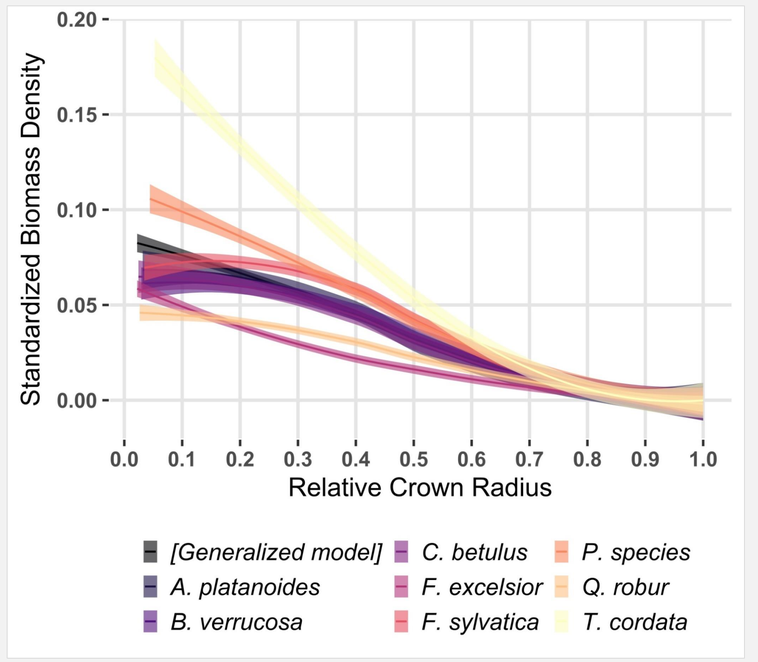


Fig. 4. Empirical *HBD* prediction model (buffered with 95% confidence interval).

Conclusion and Outlook

- We contrasted conventional approaches, and proposed *HBD* model to describe crown biomass continuously.
- *HBD* model may prove relevant in forestry applications when precision of remotely sensed biomass estimates is of interest **[2]** (**Fig. 5**).
- *HBD* would better register remote sensing (pixels) predictions with field/inventory plot biomass (**Fig. 5A**).
- *HBD* could allow to shift from 2- to 3-dimensional plot inventories; overcoming the trade-off between the plot optimization cost and remote sensing biomass predictions.

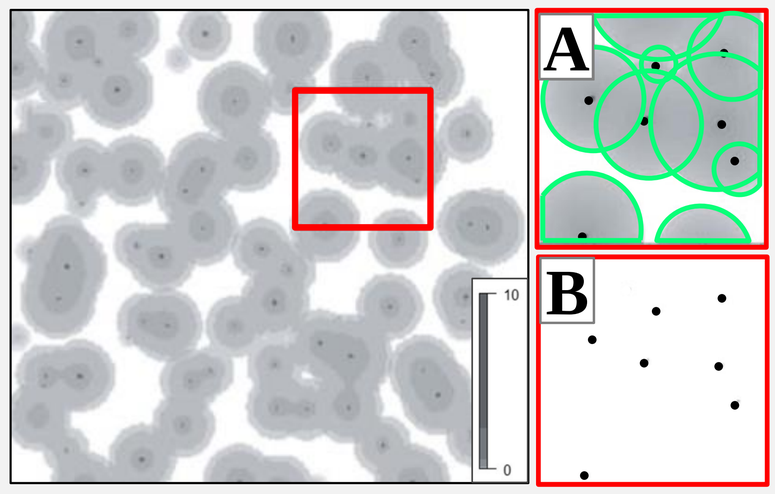


Fig. 5. Biomass estimation approaches: Assume 20*20m plot/pixel (red) **[2]**; **A:** map of biomass (kg) with *HBD (within circular crown projection area- green)*, and **B:** map of biomass with conventional approaches (biomass assigned to stem position- black point).

[1] Bazezew, M. N., Griese, N., Fehrmann, L., Kleinn, C., and Nölke, N. (2024). Modeling the horizontal distribution of tree crown biomass from terrestrial laser scanning data. *Science of The Total Environment*, 952, 175377. https://doi.org/10.1016/j.scitotenv.2024.175377

[2] Kleinn, C., Magnussen, S., Nölke, N., Magdon, P., Álvarez-González, J. G., Fehrmann, L., and Pérez-Cruzado, C. (2020). Improving precision of field inventory estimation of aboveground biomass through an alternative view on plot biomass. *Forest Ecosystems*, 7(1), 57. https://doi.org/10.1186/s40663-020-00268-7

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