MEASURING CROWN DIMENSIONS FOR TROPICAL FOREST TREES

A FIELD MANUAL

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Introduction

The term "tree crown" refers to the shape, size and placement of tree structures in three-dimensional space and to the constructional organisation of the branching system (Godin, Costes, & Sinoquet, 1999). Tree crowns form the boundary between the terrestrial biosphere and the atmosphere and determine light interception and gas exchange of carbon and water through photosynthesis and evapotranspiration (Santiago et al., 2004; Strigul et al., 2008). Crowns are one of the most physiologically and ecologically active component of trees. As such, understanding tree crown structure is important for a range of applications, including for scaling biogeochemical fluxes, modelling vegetation dynamics, and developing remote sensing methods that are seen as crucial tools for the monitoring of terrestrial ecosystems. Tree crowns vary substantially across global tropical biomes and between forest and savanna trees (Loubota Panzou et al. in review) spanning the large pantropical variation in biomass (Feldpausch et al., 2012), forest dynamics and carbon sink (Brienen et al., 2015, Hubau et al. 2020), tree height (Feldpausch et al., 2011, Banin et al. 2012), and environment (Loubota Panzou et al. in review). Their size and shape vary with structure and environment, with significant variation in crown allometry explained by precipitation, wind speed, and soil texture (Loubota Panzou et al. in review). Standardised methods are required to assess large variation in crown dimensions when estimating crown dimensions from the ground. However, ground measurements of tree crowns are challenging, time consuming, and require consideration for the large variation their position, shape, and size. Here, we outline the protocol used to estimate crown dimensions for pantropical analyses (Loubota Panzou et al. in review) and for data archived with the online forest plot data repository and analytical tool ForestPlots (www.forestplots.net).

Tree crown measurement

Crown depth (C_{dep}, m) and **crown radius** (C_r, m) are two crown dimensions that can be measured in the field (Figure 1). C_{dep} is defined as the depth of the crown (Figure 1A), calculated as the difference between **total tree height** (H in m) and the bole height defined as the height from the ground to the first living branch or to the **height to lowest foliage** (H_f in m). C_{dep} is measured for most trees using a trigonometric approach with either a manual clinometer or electronic hypsometer. Crown radii are measured in the four (north, south, east and west) or eight (north, north-east, north-west, south, south-east, south-west, east and west) cardinal directions from ground projections of crown edge to stem centre, with the person viewing the edge of the canopy standing perpendicular to the line to the bole (Figure 1B).

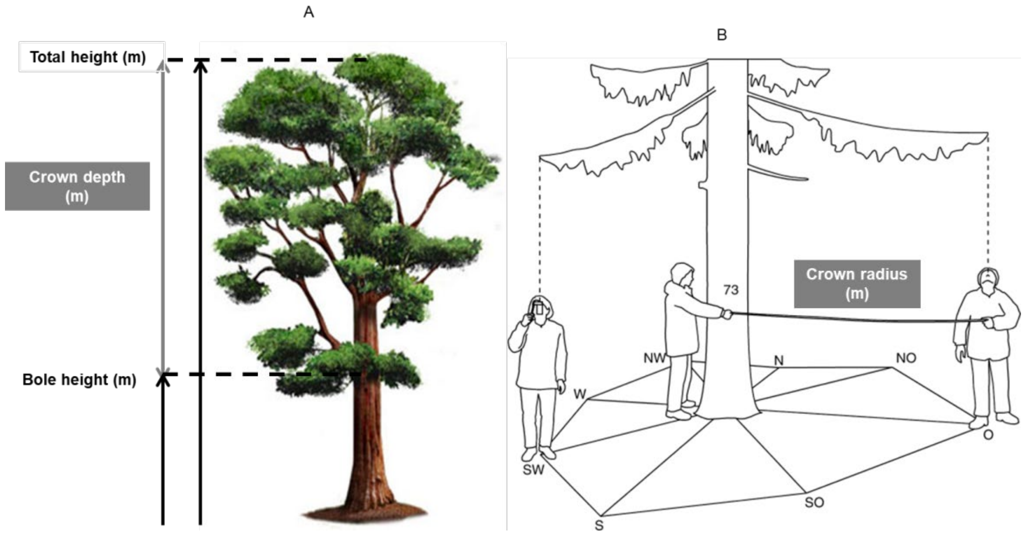

Figure 1. Measurement of crown depth (A) and crown radius (B) (image adapted from Pretzsch et al. 2015)

These basic crown measurements are used to estimate: **crown diameter** (C_{dia}, m) from 2 times the mean of the four or eight crown radii; **crown area** (C_a, m^2) from the projected area of four ellipse quarters ($\pi \times C_{r\_NS} \times C_{r\_EW}$), where C_{r_NS} is the mean of C_r north and C_r south and C_{r_EW} is the mean of C_r east and C_r west; and **crown volume** (C_v, m^3) assuming a half-ellipsoid shape as $\frac{1}{2} \times \frac{4}{3} \times C_a \times C_{dia}$.

Crown measurements can be taken during initial plot census or during plot recensus (see Phillips et al. 2016 for plot establishment and census protocols). The crown measurements can be paired in the field with estimates of tree height (Banin et al., 2012; Feldpausch et al., 2011), liana infestation (van der Heijden et al, 2010), and crown illumination (see RAINFOR protocols). Crown measurements are generally taken to evaluate the allometry of intact crowns. Therefore, field measurements exclude trees with significant crown damage. When crown measurements are taken to assess crown damage (e.g., due to selective logging), an assessment of the fraction of the crown lost to damage should be noted on the field sheets and when uploading data to forestplots.net. The number of crowns measured per site varies from 30 to 9000 trees across field sites and studies (Loubota Panzou et al. in review). An analysis of the number of tree height measurements needed to reduce uncertainty in biomass estimates suggested a conservative threshold of sampling 50 trees per location, including the ten trees with the largest diameter (Sullivan et al. 2018). A similar threshold could be taken for crown diameter measurements, with individual trees measured at the same time to save time and to evaluate crown size-bole diameter-height allometry. Crown diameter measurements can be uploaded to forestplots.net with the census data.

Damage from branch and tree-fall, wind, lianas, and logging, as well as preferential growth towards light gaps can cause asymmetric crown development. Sometimes, these changes can result in negative radii values relative to the centre point of the base of the bole. Figure 2 shows an example where the crown is shifted to the side away from the bole centre point, causing one radius to be negative. Despite this negative radius, the overall estimated crown diameter is correct.

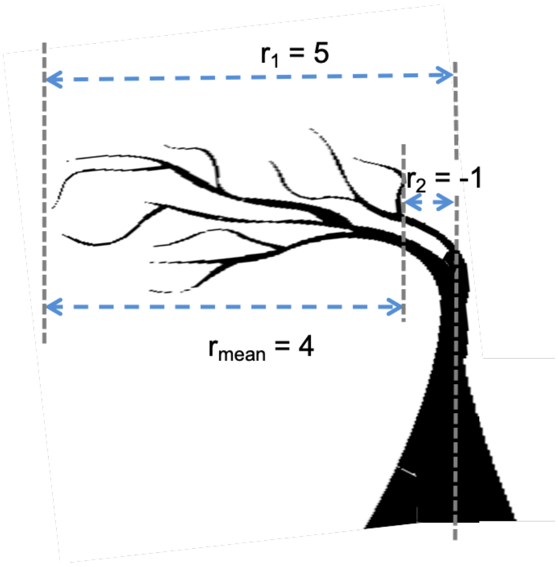

Figure 2. Source of negative radii measurements for tree crown measurements. Here, the tree crown is shifted to the side away from the centre point of the base of the bole.

Conclusions

Standardised measurements are required to accurately assess variation in global crown allometry. This measurement protocol defines the main variables, field approaches, and calculations to evaluate global tree crowns. A large dataset on crown dimensions (crown depth, crown diameter, crown area and crown volume) has been developed from Africa, America, Asia and Oceania (Loubota Panzou et al. in review) and is available in ForestPlots (www.forestplots.net), which allows the archival of tree crown data and connecting those interested in using the data with the lead authors and data managers (ForestPlots project #44).

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