

# Calculations for Coarse Woody Debris stocks and fluxes, BCI 50ha plot annual census data

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This document gives an explanation of the calculations to calculate deadwood stores and fluxes in the 50ha plot, Barro Colorado Island, Panama as part of the code package:

`**citation`

## 1 Sample level calculations

This first section contains the explanation for the sample level calculations for standing and fallen coarse woody debris, which can be found in `density calculation bci50deadwood correctedtoprocessed.Rmd`.

### 1.1 Density of Samples

Density was calculated from penetrometer measurements following the methods described in Gora et al 2019.

#### **Penetration mm per hit**

A penetrometer is used to measure the density of individual woody samples for standing and falling for censuses conducted from 2001-2020. The first step is to calculate the millimeters the penetrometer penetrated the sample per hit.

For samples where a total of 20 hits were carried out and the end penetration in mm was measured, the penetration per hit (Pen.hit.mm) is calculated by dividing the measured penetration by 20.

For samples where the penetrometer reached 200mm depth (max penetration) in less than 20 hits, the penetration per hit (Pen.hit.mm) is calculated by dividing 200 by the number of hits.

### Calculating density of sample from penetrometer measurements.

In 2010, destructive sampling of woody debris was carried out to establish the relationship between the real density (defined as the dry mass in the oven divided by the fresh volume of the disks removed from the field samples) and the depth of penetration measured using a dynamic penetrometer.

A linear relationship was calculated between the log10-transformed penetrometer penetration per hit (mm) and the log10-transformed dry density (kg/m<sup>3</sup>). This relationship was then used to predict log10-transformed density values from penetration per hit measurements.

The predicted log density values were converted back to density (kg/m<sup>3</sup>) by multiplying with a first order correction factor (CF), following the approach described in Chave et al 2005.

$$CF = 10^{\frac{RSE^2}{2}}$$

Where RSE is the residual standard error.

For samples where a penetrometer was not used the mean density of the plot taken from Gora et al 2019 was used (271 kg m<sup>-1</sup>)

## 1.2 Residence time

For fallen and standing samples, the number of years the sample is present in the dataset is calculated by counting the number of years with in which that sample occurs. The first year of appearance is taken from the first census year the code of piece for that sample appears in the dataset and the last appearance is the last census year where the piece was measured with a diameter above 200mm.

## 1.3 Fallen sample level calculations

For fallen samples, diameter width of the samples is measured where the sample crosses the transect section which is subsequently used in further calculations.

### Cross Section Mass of Downed woody debris

For fallen samples, the cross-sectional mass is calculated using the following equation:

$$M_{cs} = \rho \cdot \pi \cdot \left(\frac{D}{2}\right)^2$$

Where  $M_{cs}$  is the cross-sectional mass (kg/m<sup>3</sup>),  $\rho$  is the sample density (kg/m<sup>3</sup>), and  $D$  is the diameter of the sample where it crosses the transect (m).

**Diameter Squared** For fallen samples, the diameter squared of the cross section is also calculated as:

$$D^2$$

Where  $D$  is the diameter in m.

## 1.4 Standing sample piece level measurements

Height and Diameter at Breast Height (DBH) are measured for standing dead-wood which are subsequently used in further calculations

### Equivalent diameter at 1.3m height

For samples where the diameter was not measured at 1.3m (DBH) due to buttresses or the height of the sample being less than 1.3m, the equivalent DBH was calculated using the following model from, Table 1, model 1 of Cushman et al. 2014

$$D_E = D_i \cdot e^{b \cdot (POM - 1.3)}$$

Where  $D_i$  is the measured diameter,  $POM$  is the height of the measurement (m), and  $b$  is the taper correction parameter.  $b$  is calculated using from Model 2 of Cushman et al. 2021 - parameters in Table 2, model 2, and in Table S9.

$$b = 0.156 - 0.023 \cdot \ln(D_i) - 0.021 \cdot \ln(POM) + 0.00057$$

### Volume of Standing sample

The volume of individual standing samples are calculated using three approaches, depending on whether the sample has all branches present, partial branches present or no branches.

a. For samples with all branches present, the volume is calculated using the following equation

$$V = \pi \cdot H \cdot \left(\frac{D}{2}\right)^2$$

Where  $V$  is the volume ( $m^3$ ),  $H$  is the height of the standing piece (m), and  $D$  is the equivalent diameter at 1.3 m (m).

b. For samples with part of the canopy remaining, the equation above is used and then multiplied by 0.875 to assume half of the canopy is lost, which makes up a quarter of the total above ground volume.

c. For samples without branches, they are treated as truncated cones following the methodology in Gora et al 2019, and the volume is calculated using the following equation:

$$V = \frac{1}{3} \cdot \pi \cdot H \cdot \left[ \left( \frac{D}{2} \right)^2 + \left( \frac{d}{2} \right)^2 + \frac{D \cdot d}{4} \right]$$

Where  $V$  is the volume ( $\text{m}^3$ ),  $H$  is the height of the standing piece (m),  $D$  is the equivalent diameter at 1.3 (m), and  $d$  is the diameter at the top of the piece, calculated using the taper correction function.

**Mass of standing woody pieces** The mass of individual standing samples are calculated using three approaches, depending on whether the sample has all branches present, partial branches present or no branches.

a. For samples with all branches, above ground biomass (AGB) is calculated using the equation described in Chave et al 2014 and used in Gora et al 2019:

$$AGB = \exp \left( -1.803 - 0.976 \cdot E + 0.976 \cdot \ln(\rho) + 2.673 \cdot \ln(D) - 0.0299 \cdot \ln(D^2) \right)$$

where AGB is above ground biomass in kg,  $E$  is a region specific environmental parameter (0.0561 for BCI),  $D$  is DBH (mm), and  $\rho$  is sample density ( $\text{kgm}^3$ ).

b. For trees with only part of the canopy present, the equation above is used and then multiplied by 0.875 to assume half of the canopy is lost, which makes up a quarter of the total above ground mass

c. For samples with no branches, the mass (kg) of the samples is calculated by multiplying the volume by the density of the sample (either the average density or penetrometer estimated density in  $\text{kgm}^3$ ).

## 1.5 Decomposition rate constant of sample

The yearly decomposition rate of individual pieces was calculated from the diameter and cross-sectional mass (for fallen pieces) or the total volume and mass (for standing pieces) using the following equation:

$$K = \ln \left( \frac{C_0}{C_t} \right) \cdot \frac{1}{t}$$

Where  $K$  is the decomposition constant of a piece for time  $t$ , and  $C_0$  and  $C_t$  is the target variable at the time of first appearance (0) and last appearance ( $t$ ), respectively.

See Table 1. in Appendix for the definitions of the new columns generated from the calculations in **density calculation bci50deadwood correctedto-processed.Rmd** which can be found in the datafiles located in Data3Processed.

## 2 Scaling Up Sample-Level Estimations

The following calculations are detailed in **report V2\_bci50deadwoodCWD\_2009-2024**.

### 2.1 Subplot-Level Estimations

#### Fallen CWD Mass

The subplot-level estimated average mass ( $M$ ) of fallen coarse woody debris (CWD) in kg/m<sup>2</sup> is calculated using the following equation:

$$M = \frac{\pi}{2L} \cdot \sum M_{cs}$$

Where: Where  $L$  is the total length of the transects in the subplot (160 m).  $M_{cs}$  is the cross-sectional mass (kg/m).

#### Downed CWD Volume

The subplot-level estimated average volume ( $V$ ) of downed CWD in m<sup>3</sup>/m<sup>2</sup> is calculated using the following equation:

$$V = \frac{\pi^2}{8L} \cdot \sum D^2$$

Where  $L$  is the total length of the transects in the subplot (160 m).  $D$  is the diameter of the sample where it crosses the transect (m).

#### Standing CWD Mass

The subplot-level estimated average mass ( $M$ ) of standing CWD in kg/m<sup>2</sup> is calculated by summing the total mass of all pieces within the transect area and dividing by the transect area:

$$M = \frac{\sum M_p}{A}$$

Where  $M_p$  is the total mass of individual standing pieces (kg).  $A$  is the subplot (16000m<sup>2</sup>).

#### Standing CWD Volume

The subplot-level estimated average volume ( $V$ ) of standing CWD in  $\text{m}^3/\text{m}^2$  is calculated by summing the total volume of the pieces within the subplot and dividing by the subplot area:

$$V = \frac{\sum V_p}{A}$$

Where  $V_p$  is the volume of each piece ( $\text{m}^3$ ) and  $A$  is the area of the subplot ( $16000\text{m}^2$ )

### 3 Annual Estimations

#### 3.1 Total Annual Estimates of CWD Stocks

The total annual estimated volume ( $\text{m}^3/\text{ha}$ ) and mass ( $\text{Mg}/\text{ha}$ ) of standing and fallen CWD for the 50 ha plot is calculated by finding the mean for all subplots each year.

#### 3.2 Inputs and Outputs of Volume and Mass of CWD

We identified the new pieces of deadwood for each year based on the first appearance of the unique identifying codes (Subplot, transect letter, code of piece) and classified these as inputs for each year. The volume and mass of the inputs for each subplot per year were calculated using the equations described above.

To calculate the woody debris loss (outputs) per subplot per year, the following equation was used:

$$Output_t = Total_{t-1} + Input_t - Total_t$$

This was done for both volume and mass.

#### 3.3 Estimated Residence Time

We estimated the mean residence time of CWD using a steady-state model; we divided the mean stocks for all years by the mean inputs for all years:

$$R = \frac{MeanStocks}{MeanInputs}$$

## 4 Bibliography

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## 5 Appendix

Table 1: Dictionary of new columns in the data files located in Data 3 Processed, generated from calculations found in density calculation bci50deadwood correctedtoprocessed.Rmd

Column name	Units	Defintion	Fallen	Standing
Pen.hit.mm	mm	The depth the penetrometer penetrated the sample for a single hit.	TRUE	TRUE
pendensity.Kgm3	kg/m <sup>3</sup>	The predicted density of the sample.	TRUE	TRUE
pen density	NA	Defines whether the sample density was predicted from a penterometer measurement which TRUE meaning it was predicted and FALSE meaning the average desnity was assigned.	TRUE	TRUE
pen crossmassKgm	kg/m	The cross section mass of the fallen sample, calculated from the density multiplied with cross section area.	TRUE	TRUE
habitat	NA	The habitat type of the subplot within the 50ha plot following the BCI habitat classification system.	TRUE	TRUE
b	NA	The taper correction parameter calculated using from Model 2 of Cushman et al. 2021 Biotropica DOI:10.1111/btp.12994 - parameters in Table 2, model 2, and in Table S9.	FALSE	TRUE
mean diameter at1.3mm	mm	The diameter at 1.3m correcting for point of measurement using model from Table 1, model 1 of of Cushman et al. 2014 Methods Ecology and Evolution DOI:10.1111/2041-210X.12187.	FALSE	TRUE
Diameter.at.top .of.snag	mm	The diameter at the top of the standing sample calculated using model from Table 1, model 1 of of Cushman et al. 2014 Methods Ecology and Evolution DOI:10.1111/2041-210X.12187.	FALSE	TRUE
Volume m3	m <sup>3</sup>	The estimated volume of the standing sample.	FALSE	TRUE
AGB.Kg.dry.mass	Kg	The estimated biomass of the standing sample, calculated through multiplying the density of the sample with the volume.	FALSE	TRUE
K.diameter.yr		The exponential decay rate calculated from the diameter of fallen pieces.	TRUE	FALSE
K.csarea.yr		The exponential decay rate calculated from the area of fallen pieces.	TRUE	FALSE
K.volume.yr		The exponential decay rate calculated from thg volume of standing pieces.	FALSE	TRUE
K.mass.yr		The exponential decay rate calculated from the mass of standing pieces.	FALSE	TRUE