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Method Article

Least squares-based biomass conversion and expansion factors best estimate biomass than ratio-based ones: Statistical evidences based on tropical timber species

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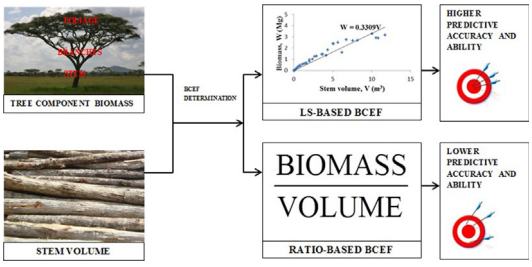
GRAPHICAL ABSTRACT



ABSTRACT

Due to its readiness to convert stem volumes (V) into biomass, national and regional aboveground biomass estimates and greenhouse gas reporting are generally based on biomass conversion and expansion factors (BCEFs). BCEF-based biomass ($\hat{W}$) is computed by the following regression through the origin (RTO): $\hat{W} = BCEF \times V$. However, the regression slope (BCEF) is not obtained using least squares (LS); it is obtained as the ratio of observed biomass and stem volume. Therefore, the sum of squares of the residuals is not minimum. This may lead to strongly biased biomass estimates. Furthermore, in this case, the biomass is not modelled. In the present study, it was suggested that BCEFs should be obtained using LS through RTO. The objective of this study was to compare LS-based and ratio-based BCEFs with regard to predictive accuracy and ability. A dataset of 75 trees from 4 species was used for the comparisons.

- LS-based BCEFs were associated with higher predictive accuracy and ability than ratio-based ones.
- It was proved that RTO is appropriated for estimating BCEFs, as the intercept α was consistently not significant.
- Ratio-based BCEFs may lead to seriously biased biomass and carbon stocks estimates.

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• BCEFs should be estimated using least squares.

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Methods details

Background

Forest biomass is a crucial ecological variable for understanding the evolution and potential future changes of the climate system [1]. Therefore, a global assessment of biomass and its dynamics is an essential input to climate change projection models and mitigation and adaptation strategies [1].

Forest biomass can be estimated non-destructively using biomass equations. When biomass equations are fitted using least squares they are called biomass regression equations. Biomass regression equations are developed as linear or non-linear functions of one or more tree-level dimensions. When biomass equations are fitted in such a way that they specify tree component biomass as directly proportional to stem volume, the ratios of proportionality are then called biomass conversion and expansion factors (BCEFs) [2].

National and regional aboveground biomass (AGB) estimates and greenhouse gas (GHG) reporting are generally based on BCEFs [2,3], mainly because of its readiness to convert standing stem volumes from forest inventories into different tree component biomasses [4], including the non-commercial components (foliage, needles, branches, root system, etc.) [5].

BCEF-based biomass is computed by the following equation

$$\hat{W} = BCEF \times V \quad (1)$$

where $\hat{W}$ is the predicted tree component biomass and V stem volume.

Eq. (1) is, actually, a regression through the origin (RTO) of biomass on stem volume where, therefore, the BCEF value is the slope. However, the regression slope (BCEF) is not obtained using least squares (LS), but as the ratio of observed tree component biomass and stem volume [2,6]. Hence, the sum of squares of the residuals is not minimum, which may lead to strongly biased biomass estimates. Furthermore, in this case, the biomass is not modelled [2].

The assumption behind Eq. (1) is that tree component biomass is directly proportional to stem volume and that if stem volume is zero, then concurrently, tree component biomass is zero, which is true. Therefore, the ratio estimators are deemed appropriate [7–10], and BCEF is then computed as such (i.e. using ratio estimators). Nonetheless, as mentioned previously, it fails by not using least squares and not modelling the biomass. Therefore, fitting Eq. (1) using RTO – i.e. obtaining BCEF in Eq. (1) using least squares – might provide more accurate biomass estimates than using ratio estimators (ratio-based BCEFs).

The objective of this study was to compare LS-based and ratio-based tree component BCEFs with regard to predictive accuracy and ability. The study addressed the following research question: do LS-based- and ratio-based BCEFs differ in terms of predictive accuracy and ability? It was hypothesized that LS-based tree component BCEFs provide most accurate and reliable estimates.

Data acquisition

The study was conducted in Mozambique (18° 15′S, 35° 00′E), in Gaza, Inhambane and Sofala provinces. Seventy five (75) trees from four valuable timber species were destructively sampled for biomass and volume estimation, namely: *Colophospermum mopane* Kirk ex J. Leonard, *Afzelia quanzensis* Welw., *Millettia stuhlmannii* Taub., and *Pterocarpus angolensis* DC.