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DBH thresholds systematically bias biomass estimates and stand structural analyses in African savannas

Ahmed M M Hasoba[1,2,*] and Kornel Czimber[1]

1 Institute of Geomatics and Civil Engineering, Faculty of Forestry, University of Sopron, Bajcsy-Zsilinszky ut. 4, Sopron 9400, Hungary
2 Faculty of Forest Sciences and Technology, University of Gezira, Wad Madani, Sudan
* Author to whom any correspondence should be addressed.

E-mail: Hasoba.Ahmed@phd.uni-sopron.hu and Ahmedhasoba899@gmail.com

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1. Introduction

Savannas cover nearly one-fifth of the Earth's land surface and contribute substantially to global terrestrial carbon storage and land–atmosphere interactions [1]. Accurate assessment of aboveground biomass (AGB) in African savannas is critical for global carbon accounting, ecosystem management, and climate policy. This assessment relies heavily on the diameter at breast height (DBH), the trunk diameter measured at 4.5 feet (about 1.37 m) [2, 3], which underpins forest inventories, allometric biomass models, stand structure analyses, and national greenhouse gas (GHG) reporting frameworks [4]. DBH is also a key parameter for distinguishing woody life stages (i.e. Seedling, Sapling, and Mature trees) [5] and for linking plot-level data to regional and national carbon assessments [6].

Notwithstanding its significance, DBH introduces a persistent methodological challenge in savanna ecosystems: there is no consistent threshold for defining which woody stems qualify as 'trees' in inventories [7, 8]. Unlike closed-canopy forests, African savannas exhibit a continuous structural gradient from large fire-resistant trees to multi-stemmed shrubs and regenerating coppice shoots [9]. Consequently, inventory thresholds vary widely (e.g. $\geqslant 2$, $\geqslant 5$, $\geqslant 10$ cm), and each choice fundamentally alters estimates of stem density, species composition, and biomass. Although this Perspective focuses on African savannas, similar challenges occur in Tropical dry forests, where heterogeneous stand structures and abundant small-diameter woody stems can likewise influence biomass estimation and ecological interpretation.

Threshold selection is therefore not a marginal methodological detail but a major source of systematic bias. Small-diameter stems dominate stem counts in savannas [10] and can cumulatively contribute substantial biomass, particularly in degraded or recovering systems where juvenile cohorts prevail [11]. Excluding these stems can underestimate biomass and obscure regeneration dynamics, whereas including very small individuals may increase stem density and hinder comparability across studies [12]. Moreover, DBH-related uncertainty can exceed that associated with the choice of allometric model, and measurement errors near threshold boundaries may propagate into 10%–20% uncertainty in carbon estimates [13]. This pattern is not confined to savannas: in northern boreal peatland forests, excluding small-diameter stems has been shown to bias growth-trend estimates in a consistent, positive direction, because the omitted biomass is concentrated in young cohorts [14].

These issues are especially consequential in Africa, where savanna inventories inform GHG reporting, reducing emissions from deforestation and forest degradation (REDD+), initiatives, the African Forest Landscape Restoration Initiative (AFR100), and biodiversity assessments [15]. While shrub and coppice biomass may be quantified through whole-plot destructive harvesting, thereby avoiding individual-shoot measurements, most regional and national assessments depend on DBH-based inventories and allometric equations. Yet, DBH thresholds are rarely standardized or explicitly justified. Here, we argue that DBH threshold selection is an under-recognized methodological choice that systematically shapes savanna biomass and diversity estimates, and we propose an evaluative framework to identify, quantify, and transparently report this hidden source of uncertainty, providing a foundation for future threshold-adjustment methods.

2. How DBH thresholds shape reported savanna structure

Minimum (DBH) thresholds applied in African savanna inventories vary widely across regions, ecological contexts, and study objectives (table 1). In Sudan savanna, reported thresholds range from ⩾5 cm to ⩾10 cm [16],with some large-scale surveys omitting explicit DBH criteria altogether despite reporting broad ranges of stem density. Similar variability is evident across the African savanna biome, where thresholds span from very low cut-offs (⩽2 cm) in Sudanian systems to ⩾15 cm in some miombo woodlands. Semi-arid and Sahelian savannas commonly apply intermediate thresholds (⩾5–6 cm), while ⩾10 cm is frequently used in production-oriented or management-focused inventories. Although such variation may reflect differences in vegetation structure, land-use intensity, or management priorities, DBH thresholds are rarely explicitly justified. As a result, studies addressing comparable ecological questions employ inconsistent tree definitions, substantially limiting the comparability of estimates of structure, diversity, biomass, and carbon stocks across sites and regions. These results show that DBH thresholds strongly influence estimates of savanna biomass and structure analysis because they determine which individuals are included in forest inventories.

3. An illustrative quantitative demonstration

This study does not present a new biomass dataset; instead, it uses previously collected raw inventory data from a savanna woodland in southeastern Sudan as an illustrative example to demonstrate how DBH threshold selection propagates into large differences in structural and biomass estimates. The goal is not to introduce a new regional biomass assessment, but to reveal a largely overlooked methodological driver of uncertainty in savanna carbon accounting. Structural and biomass metrics were recalculated under four commonly used minimum DBH thresholds (5, 7, 10, and 15 cm), representing the range of cut-offs frequently applied in African savanna inventories. These thresholds were selected to reflect the diversity of practices reported in the literature and to quantify the sensitivity of biomass and structural estimates to threshold selection, rather than to identify or recommend an optimal minimum DBH threshold. For each threshold, stem density (stems ha^{-1}), basal area (m^2 ha^{-1}), and (AGB; Mg ha^{-1}) were estimated using species-specific wood density values and a height-inclusive allometric model.

Applying alternative minimum DBH thresholds produced large, non-linear changes in estimated savanna structure and biomass (figure 1; appendix A). Using a 5 cm threshold as the reference, increasing the minimum DBH to 7 cm resulted in only minor reductions in stem density (−2.9%), basal area (−0.9%), and AGB (−0.9%). In contrast, raising the threshold to 10 cm reduced stem density by 38.2%, while basal area and biomass declined by 22.5% and 22.2%, respectively. This comparison serves as a worked template for the missing-biomass calculation formalized in section 5: it demonstrates, using field data, how much structural and biomass signal is lost below a given cutoff, and can be reproduced by other studies using their own diameter-distribution data.

The most pronounced effects were observed at a 15 cm threshold, which excluded more than 92% of stems and reduced estimated basal area and AGB to approximately one-quarter of the values obtained at 5 cm. These non-linear, threshold-dependent differences show that DBH cut-offs systematically distort fundamental woodland attributes and carbon stock estimates. Threshold selection does not produce marginal adjustments; it generates multiplicative changes in estimated savanna structure and biomass.

4. Why DBH thresholds matter: three consequences

4.1. Carbon accounting bias

DBH thresholds systematically shape which woody biomass are counted, and therefore directly propagate uncertainty into terrestrial carbon budgets. Higher thresholds systematically exclude small-diameter stems that dominate savanna structure, leading to substantial underestimation of AGB. Because savannas contribute significantly to regional and continental carbon stocks, this bias scales upward into Earth-system carbon accounting, GHG inventories, and mitigation mechanisms such as REDD+, where methodological consistency is critical.

4.2. Misinterpretation of degradation and recovery

Thresholds ⩾10–15 cm render regeneration, coppicing, and early recovery processes effectively invisible, despite these dynamics governing savanna resilience under climate variability, fire, and land-use pressure. Multi-stemmed growth forms in savanna woodlands often result from repeated coppicing and resprouting after disturbance, a key recovery mechanism that can trap trees in shrub-like stages. Although typically linked to fire and herbivory, similar responses are strongly triggered by human activities such as shifting cultivation, fuelwood and pole

Table 1. Minimum DBH thresholds used in selected African savanna and dry woodland studies, illustrating variation in tree definition across regions and study objectives.

Study	Region	Savanna Type	Minimum DBH (cm)	Study focus
[17]	Sudan	Savanna Woodland	⩾10	Species Diversity
[18]	Sudan	LowRainfall Savanna	⩾7	Species Diversity & Carbon Stock
[10]	Sudan	Savanna Woodland	⩾5	Species Diversity & Stand structure
[19]	Tanzania	Miombo woodlands	⩾15	Stand structure
[20]	Burkina Faso	Sahelian and Sudanian savannas	⩾10	Stand structure
[21]	Zambia	Miombo woodlands	⩾10	Stand structure, Biomass
[22]	Cameroon	Sudano-Sahelian Savanna	⩾10	Carbon stock estimation
[23]	Malawi	Miombo woodland	⩾5	Biomass estimation
[24]	Ethiopia	Semi-arid woodland	⩾2.5	Species diversity & Stand structure
[25]	South Africa	Savanna woodland	⩾2	Biomass estimation

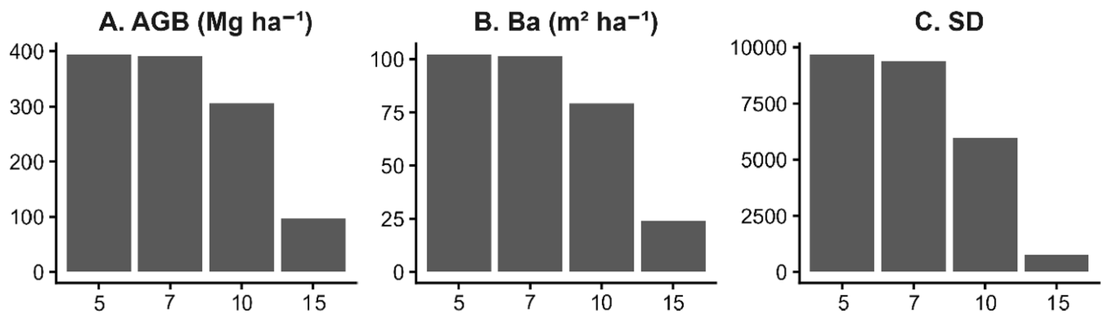

Figure 1. Sensitivity of (A) above-ground biomass, (B) basal area, and (C) stem density to alternative minimum DBH thresholds (5–15 cm) in the Nuara Reserved Forest, Sudan.

harvesting, and fodder collection, so these architectures often reflect ongoing land-use pressure more than natural growth habit [26, 27]. As a result, structurally dynamic systems may be misclassified as degraded or static, distorting assessments of ecosystem condition, restoration success, and long-term land-surface feedback relevant to environmental change analyses. Because stands dominated by small-diameter stems may reflect either degradation or active post-disturbance recovery, distinguishing between these opposite trajectories requires explicit inclusion of small stems in monitoring; a high-DBH threshold alone cannot resolve this directional ambiguity [28, 29].

4.3. The illusion of comparability

The observed variation across DBH thresholds underscores a major barrier to cross-study comparability. Biomass estimates for the same plot differed by a factor of four depending solely on the minimum DBH applied. Under such conditions, comparisons of biomass, structure, or degradation status across regions, monitoring periods, or management regimes become scientifically meaningless unless DBH definitions are explicitly aligned. Without standardized or transparently reported thresholds, apparent differences among studies can look like real ecological variation when they are actually methodological artifacts.

5. A framework for evaluating DBH threshold sensitivity

To reduce the pervasive but largely unacknowledged uncertainty introduced by variable tree-definition criteria, we propose a simple evaluative framework centered on transparency, tiered reporting, and ecological relevance. First, forest and savanna studies should be required to clearly report and justify the minimum DBH threshold used, with strong alignment to the primary objective of the study, whether carbon accounting, biodiversity assessment, or management evaluation. Second, where feasible, inventories should adopt a tiered data-collection approach in which all woody individuals above a low threshold (e.g. ⩾2.5 cm DBH) are recorded, while results are systematically reported at multiple standardized cut-offs (e.g. ⩾2.5, ⩾5 cm, and ⩾7 cm) to enable cross-study comparability. Third, significant emphasis should be placed on developing and applying diameter-class and species-specific allometric equations adapted to savanna systems, specifically for small-diameter stems that dominate structure and regeneration dynamics. Finally, future research should build on these approaches to develop and validate threshold-adjustment models capable of estimating biomass omitted under alternative DBH thresholds. Together, these steps provide a practical framework for diagnosing DBH threshold sensitivity and improving comparability across studies; without such explicit consideration, uncertainty in savanna biomass and structure estimates will stay rooted in methodology instead of ecology.

6. Conclusion

This study shows that DBH threshold selection is a dominant control on savanna structural metrics, not a neutral sampling detail. Small changes in the minimum DBH used to define trees generate large divergences in estimated biomass and carbon stocks, confirming that threshold choice shapes how savanna ecosystems are measured and reported. Savannas cover roughly 20% of the global land surface and store substantial terrestrial carbon, so inconsistencies in DBH thresholds introduce a potentially significant source of uncertainty in regional and global biomass estimates. We therefore argue for transparent, purpose-driven threshold selection, tiered reporting of structural metrics across multiple DBH classes, and diameter-class-specific allometric models to improve comparability among savanna studies. Without explicit consideration of DBH thresholds, differences in reported biomass and structure can easily be mistaken for genuine ecological variation when they are, in fact, methodological artifacts. Addressing this issue matters because savanna biomass estimates feed directly into Earth-system science, climate policy, and GHG accounting, where they need to reflect ecological reality, not hidden methodological assumptions.

Data availability statement

The data cannot be made publicly available upon publication because they are owned by a third party and the terms of use prevent public distribution. The data that support the findings of this study are available upon reasonable request from the authors.

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Author contributions

Ahmed M M Hasoba 0000-0002-7704-9385
Conceptualization (lead), Formal analysis (lead), Methodology (lead), Visualization (lead), Writing – original draft (lead), Writing – review & editing (lead)

Kornel Czimber
Conceptualization (supporting), Supervision (lead)

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