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Deadwood carbon pool and uncertainty estimates: effects of decay status and vegetation types

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Deadwood carbon pool is a crucial component of forest ecosystems and the global carbon cycle. Assessing of deadwood carbon is challenging due to variability in decay status, species and disturbances in tropical forests. Quantifying the magnitude of uncertainty is essential for improving the accuracy of carbon stock estimations. This study aimed to estimate deadwood carbon pool by considering deadwood decay status and different vegetation types as well as the associated uncertainty in carbon stock estimates. Based on the National Forestry Resources Monitoring and Assessment of Tanzania (NAFORMA) sampling design, we analysed 21,946 data points from 1,798 plots. A two-way Analysis of Variance (ANOVA) was used to examine the variation in deadwood carbon stock (rotten and solid) between the primary vegetation types. Tukey's Honest Significant Difference (HSD), post-hoc test was applied to determine which vegetation types significantly differ in carbon stock while a paired samples *t*-test was used to compare carbon stock of solid and rotten deadwood. Uncertainty was calculated using Equation 10 of 2006 IPCC Guidelines with 95% confidence interval. The estimated deadwood carbon stock ranged from 0.11 to 1.01 t C ha^{-1}, with solid deadwood having higher carbon stocks than rotten deadwood, accounting for 0.79% of total estimated carbon stocks. Carbon uncertainty values ranged from 0.0008 to 0.28%, with the highest and lowest uncertainty values from rotten deadwood in cultivated land and woodland, respectively. However, these variations among vegetation types did not significantly impact the deadwood carbon stock. In contrast, decay status had a significant effect on deadwood carbon stock. These findings are crucial for national climate policies, land use contributions to national carbon accounting, REDD+ mechanisms and sustainable management of natural ecosystems.

KEYWORDS
carbon stock, deadwood, decay status, NAFORMA, uncertainty

1 Introduction

Deadwood represents a significant carbon pool in forest ecosystems and constitutes a substantial component of the global carbon cycle (Pfeifer et al., 2015; Wijas et al., 2024; Oswalt et al., 2008). Decomposition of deadwood is a dynamic process during which carbon is primarily lost as carbon dioxide (CO_2) to the atmosphere, while a portion is transferred to soil carbon pool, although the exact partitioning varies with climate, wood traits, decomposer communities and decay stage (Griffiths et al., 2021; Wijas et al., 2024). Deadwood carbon stocks in standing dead trees and other fallen woody debris, alive or dead, vary widely across different ecosystems depending on various factors such as climate (Weggler et al., 2012), vegetation type (Paletto et al., 2012) and disturbance history such as fire or wind throw (Bauhus et al., 2018), decomposition rates (Tavankar et al., 2022), geographic region (Oettel et al., 2020), forest stand structure and composition (Oswalt et al., 2008) and forest management practices (Thorn et al., 2020). In general, temperate and boreal forests accumulate higher deadwood carbon stocks than tropical forests due to lower temperatures and slower decomposition rates, allowing deadwood to persist for longer periods (Mazziotta et al., 2014).

Tropical forests and woodlands also consist of a substantial amount of deadwood as standing dead trees or fallen woody debris, which form an essential component of the deadwood carbon pool (Bauhus et al., 2018; Woodall and Williams, 2005). Standing and downed deadwood are essential in providing resources and habitats for a wide range of plants, fungi and animal species (Brockerhoff et al., 2017), facilitating plant regeneration (Dittrich et al., 2014) and store nutrients (Godoy et al., 2012). Tanzania has a diverse range of vegetation types each with unique characteristics and different levels of deadwood accumulation and decomposition rate (McElhinny et al., 2005). Miombo woodlands, one of the largest ecosystems in Tanzania is under high anthropogenic pressure such as agriculture expansion, charcoal making, frequent burning, extensive herbivores and livestock grazing (Jonsson et al., 2005), which potentially affecting deadwood accumulation. Despite being substantial, deadwood in rainforests, dry forests, woodlands and savannas of tropical ecosystems have been largely overlooked until recently (Pfeifer et al., 2015).

The Intergovernmental Panel on Climate Change (IPCC, 2003) recognizes deadwood as one among the five carbon pools that must be quantified and monitored for accurate carbon accounting. The subsequent 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), emphasizes the need for accurate deadwood carbon stock estimations for reporting to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. More recently, accurate accounting of the deadwood carbon pool is increasingly recognized as essential for climate change mitigation initiatives such as Reducing Emissions from Deforestation and Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+).

The estimation of deadwood carbon stock is accompanied by several sources of uncertainty that can lead to inaccuracies (Griffiths et al., 2021). The primary sources of uncertainties include climate variabilities (Seibold et al., 2021), species types, sampling design, dead wood and debris measurement error (Holdaway et al., 2014) as well as differences in combustion processes when deadwood is burned rather than allowed to decompose due to combustion temperature, oxygen supply and moisture content (Hekkala et al., 2016). Estimating the magnitude of uncertainty across different vegetation types and wood decay stages is therefore important for a better understanding of the role of deadwood in ecosystem carbon dynamics and its overall carbon storage potential.

Among the five carbon pools, the deadwood carbon pool is often overlooked or not accurately estimated in various national reports such as the Forest Reference Emission Levels (FRELs) by many tropical countries. This is primarily due to the absence of national forest inventory data covering the different vegetation types and wood decay status. Previous reports in Tanzania have estimated total carbon stocks across the different land cover classes (Mauya et al., 2019; URT, 2017). However, these assessments did not account for uncertainties in estimating deadwood as a separate carbon pool, nor did they consider the effects of woody decay status on carbon estimates.

Drawing on the extensive National Forestry Resources Monitoring and Assessment of Tanzania (NAFORMA), the current study aims to estimate the deadwood carbon pool and assess the associated uncertainties across different vegetation types, considering variations in decay status. The specific objectives are (1) to estimate deadwood carbon stocks across the primary vegetation types in Mainland Tanzania stratified by deadwood decay status and (2) to assess the uncertainties associated with deadwood carbon estimates across primary vegetation types and deadwood decay status.

2 Materials and methods

2.1 Study area

This study covered the main forest types of the entire Mainland Tanzania (Figure 1) which include deciduous miombo woodlands in the western, central, and southern parts, *Acacia-Commiphora* woodlands in the north, mangrove forests along the Indian Ocean coast, and closed canopy forests that grow on the ancient mountains of the Eastern Arc. Tanzania has a mainly tropical climate but has regional variations due to topography. Temperatures range between 10 °C and 20 °C during cold and hot seasons, respectively. The mean annual rainfall varies from below 500 mm to over 2,000 mm per annum, with shot rains from October to December and long rains from March to May.

Since deadwood accumulation varies across land cover classes, this study considered the primary vegetation types which included bushland, cultivated land, forest, grassland, open land, other areas, wetlands and woodland with different vegetation type sub-class, according to NAFORMA (2015) as shown in Table 1.

2.2 Data and sampling design

This study employed data from the National Forestry Resources Monitoring and Assessment of Tanzania (NAFORMA) fieldwork which occurred between 2010 and 2014 as described in detail in Tomppo et al. (2014). The NAFORMA sampling design followed double sampling strategy for stratification and optimal allocation of plots (Tomppo et al., 2014; URT, 2017). The first phase of sampling consists of clusters of plots laid at distances of 5 km × 5 km over Mainland Tanzania. The country was divided into 18 strata based on predicted growing stock, accessibility and slope. The second phase samples were systematically selected from the first phase sample using optimal allocation. Accordingly, higher sampling intensity was allocated to strata with high variation and high predicted growing stock, while low sampling intensity was allocated to strata with low variation and low predicted growing stock.

Concentric circular plots of 15 m radius were used as the sampling units and plots were grouped into clusters as measurement units in order to increase the accuracy of the measurements and sampling intensity. The plots were grouped in L-shaped clusters and the number of plots per a cluster varied from 6 to 10, depending on the accessibility of the plots. A total of 21,946 data points were measured from 1798 plots which were spatially distributed as shown in Figure 2 and the

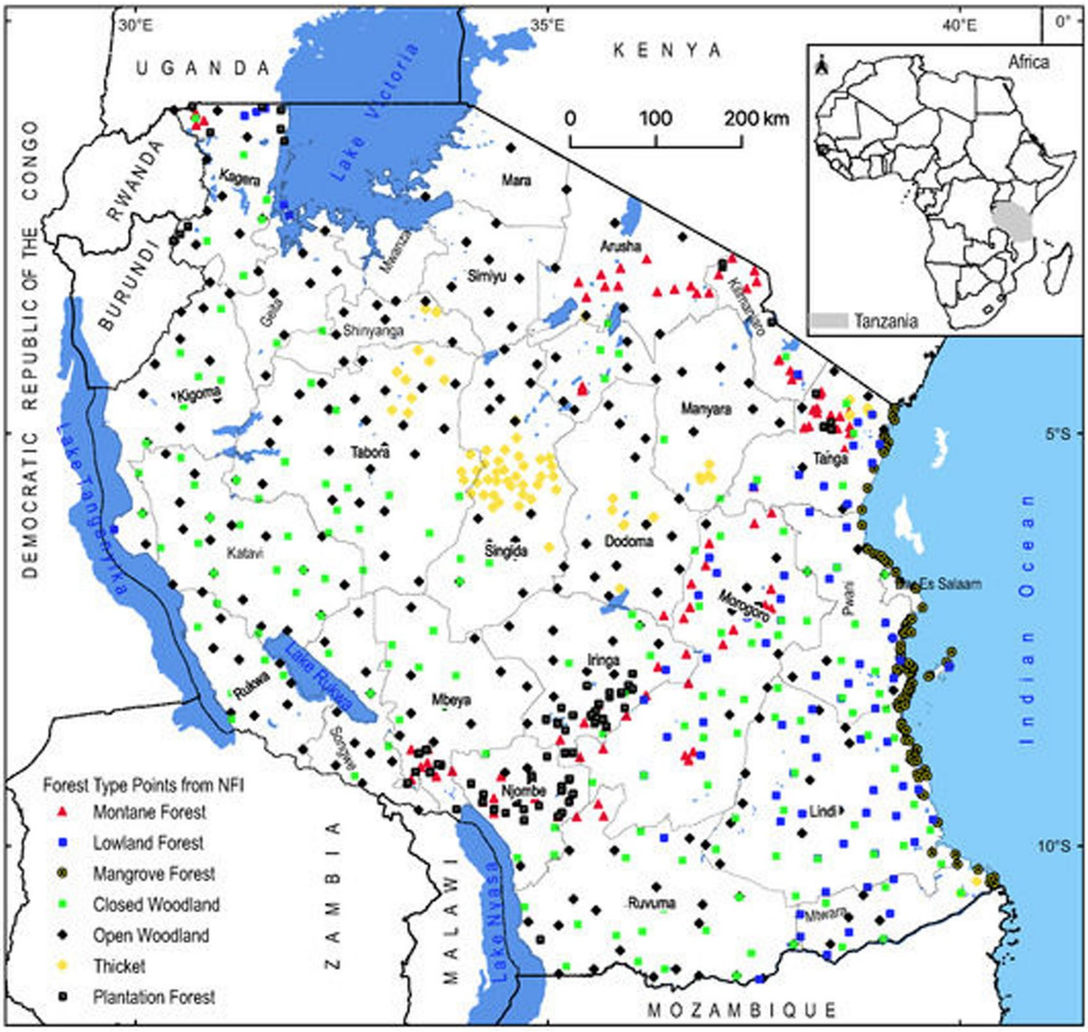

FIGURE 1
Distribution of different forest types in Tanzania Mainland.

distance between plots within a cluster was 250 m (Figure 3), while the distance between clusters varied by stratum, from 10 to 45 km. Measurements were only taken for fallen deadwood and large branches which were within a radius of 15 m plot. Measured deadwood parameters included deadwood length, diameter (top and bottom) for deadwood with a diameter equal to or greater than 10 cm and deadwood decay status (solid and rotten) according to Tomppo et al. (2014). Deadwood lengths were measured using a tape measure, and deadwood diameters were measured using a vernier caliper. Each deadwood decay status class (solid or rotten) was detected using a knife test and recorded following NAFORMA field manual (Tomppo et al., 2014; URT, 2017).

2.3 Data analysis

2.3.1 Deadwood biomass

Deadwood biomass was estimated by multiplying the volume of each deadwood species with its specific wood density. Species-specific wood density values were sourced from the Global Wood Density database (Zanne et al., 2009), using the function getWoodDensity() in R. For those species-specific wood density values that were missing from the database, a default wood density value of 500 kg/m³ was used (Tomppo et al., 2014). Irrespective of species, a default wood density reduction factor of 0.97 was used for solid woods and 0.45 for rotten deadwood (IPCC, 2006). Smalian formula was adapted for calculating deadwood volume (Equation 1).

$$V = \pi\left(d1^2 + d2^2\right)L/8 \tag{1}$$

Where: V is Volume (m^3) of the deadwood, d1 and d2 (cm) are the diameter at both ends of the deadwood, and L is the length of the deadwood (m).

The estimated deadwood volume and biomass of individual values were then summed up and scaled up to per ha basis for each vegetation type sub-class.

2.3.2 Weighted deadwood biomass

Deadwood biomass for each vegetation type sub-class (explained in Table 1), was estimated per plot and then weighted based on their corresponding areas (Equation 2).

TABLE 1 Classification of different vegetation types in Mainland Tanzania.

Primary vegetation type	Vegetation type sub class	Area (ha)
Bushland	Dense	2,012,400
	Emergent trees	309,400
	Open	2,843,500
	Scattered cultivation	1,162,700
	Thicket	971,900
	Thicket with emergent trees	308,300
Cultivated land	Agroforestry system	1,373,000
	Herbaceous crops	5,045,400
	Mixed tree cropping	154,700
	Wooded crops	1,521,100
Forest	Humid Montane	995,300
	Lowland	1,656,500
	Mangrove	158,100
	Plantation	554,500
Grassland	Bushed	438,900
	Open	3,091,100
	Scattered cropland	593,600
	Wooded	4,712,300
Woodland	Open	35,997,300
	Scattered cropland	2,530,900
	Closed	8,729,000
Open land	Bare soil	161,100
	Rock outcrops	73,100
Other areas	Other areas	1,892,700
Wetlands	Inland water	154,700
	Swamp	1,007,900

$$Yi = \frac{\sum_{i=1}^{n}\left(X_i \times a_i\right)}{\sum_{i=1}^{n}\left(a_i\right)} \tag{2}$$

Where Y_i is the weighted estimate of deadwood biomass per ha, a_i is the area of vegetation type sub-class i, X_i is deadwood biomass per ha of the vegetation type sub-class and n is the number of vegetation type sub-classes in the primary vegetation type.

2.3.3 Deadwood carbon stock

Individual weighted deadwood biomass was converted into carbon stocks by multiplying with a carbon conversion factor of 0.47 (IPCC, 2006) and later aggregated into carbon stock density, i.e., carbon stock per ha for each primary vegetation type.

2.3.3.1 Effect of vegetation types on deadwood carbon

A two-way Analysis of Variance (ANOVA) was used to examine the variation in deadwood carbon stock (rotten and solid) between the primary vegetation types. Tukey's Honest Significant Difference (HSD), post-hoc test was applied to determine which vegetation types significantly differ in carbon stock.

2.3.3.2 Effect of decay status on deadwood carbon

To compare the carbon stock between solid and rotten deadwood across the primary vegetation types, a paired samples *t*-test was performed. The test examined whether the mean carbon stock of solid and rotten deadwood differed significantly across the primary vegetation types.

2.3.4 Uncertainty estimation

The uncertainty was estimated by calculating the sample mean, variance based on the samples, standard deviation and confidence interval (Equations 3 and 4). Uncertainty was expressed by a 95% confidence interval constructed using samples from the same sampling design, including the true value (IPCC, 2006) (Equation 5).

Variance based on samples was calculated using the following Equation 3:

$$S^2 = \frac{\sum\left(xi - \bar{x}\right)^2}{n-1} \tag{3}$$

Standard deviation was estimated as the square root of the variance.

$$S = \sqrt{\frac{\sum\left(xi - \bar{x}\right)^2}{n-1}} \tag{4}$$

Uncertainty for each vegetation type was calculated by using equation 10 of IPCC (2006). The term "uncertainty" was based on the 95% confidence interval.

$$U_{total} = \frac{\sqrt{\left(U_1 \times X_1\right)^2 + \left(U_2 \times X_2\right)^2 + \ldots + \left(U_n \times X_n\right)^2}}{\mid X_1 + X_2 + \ldots + X_n \mid} \tag{5}$$

Whereby, U_{total} = Percentage uncertainty of the sum of quantities (half the 95% confidence interval, divided by the total (i.e., the mean) and expressed as a percentage).

X_i and U_i = Uncertainty quantity and the associated percentage uncertainties, respectively.

3 Results

3.1 Deadwood carbon stock

The estimated deadwood carbon stock across different primary vegetation types ranged from 0.11 to 1.01 t C ha^{-1} (Figure 4). Forests exhibited the highest deadwood carbon stock (1.01 ± 0.00057 t C ha^{-1}) compared to other vegetation types, followed by woodlands (0.8 ± 0.0004 t C ha^{-1}) while grasslands had the

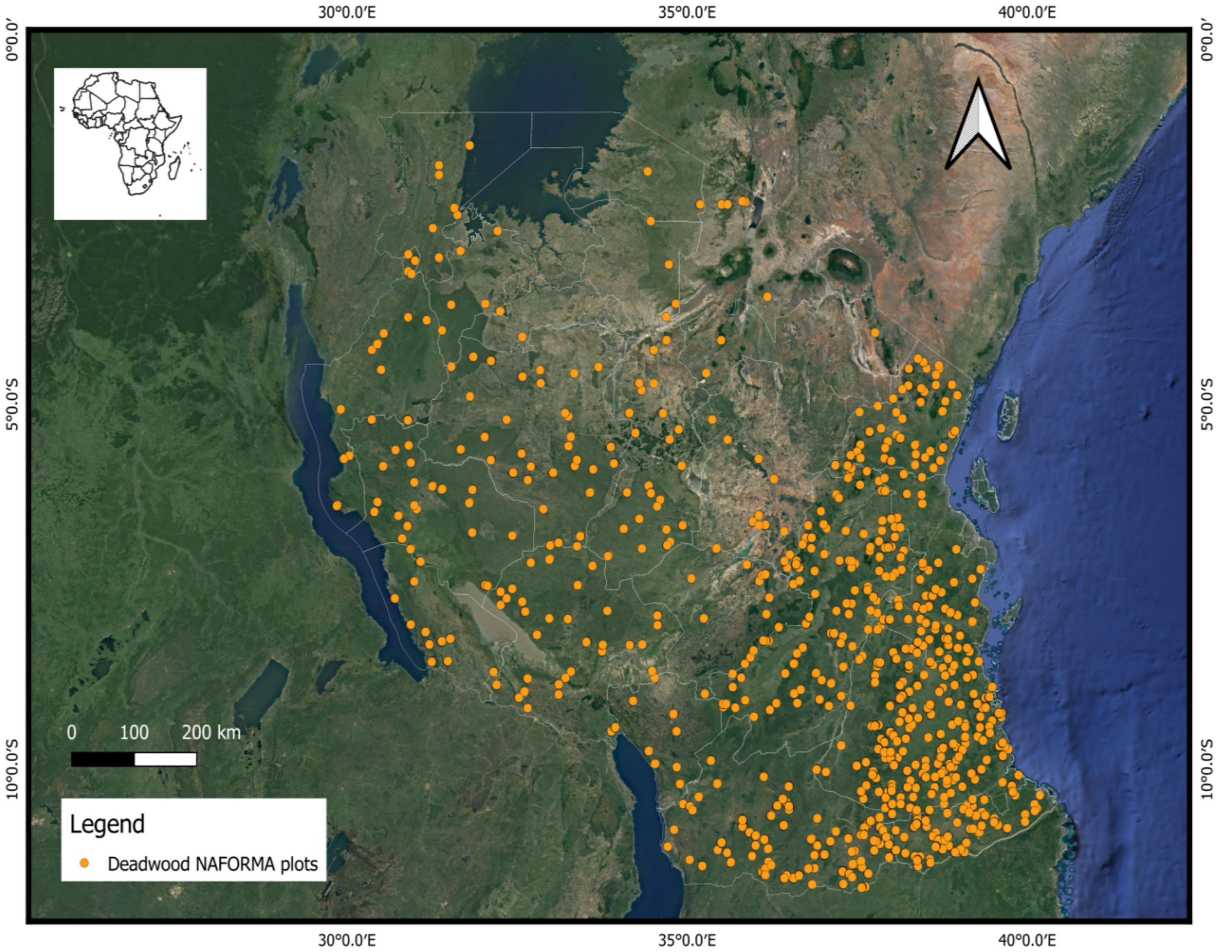

FIGURE 2
Distribution of deadwood sample plots in Tanzania Mainland.

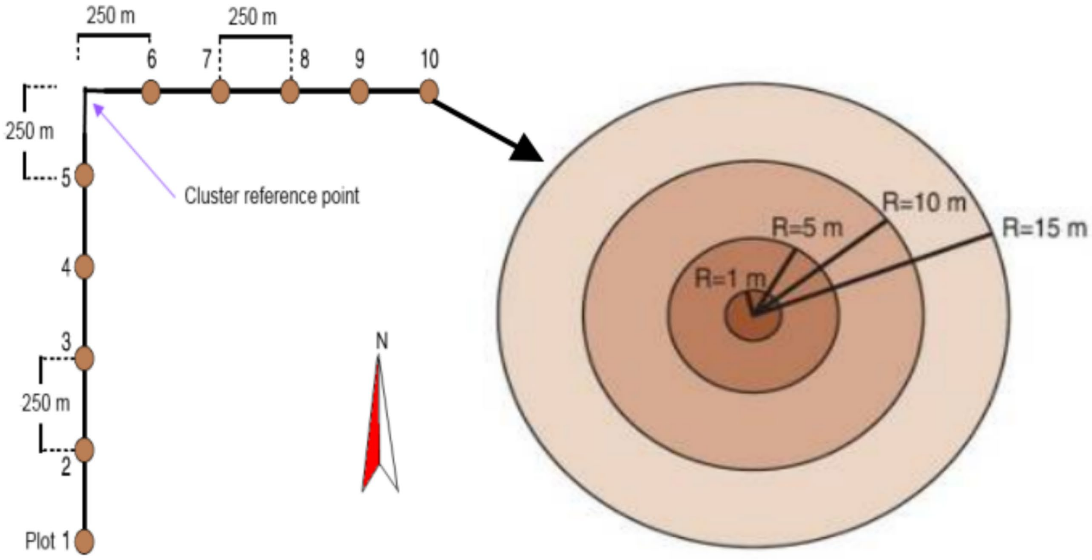

FIGURE 3
NAFORMA plots laid within L shaped cluster design (plots are indicated by the brown solid circles).

lowest deadwood carbon stock (0.16 ± 0.0017 t C ha^{-1}). However, these variations among vegetation types did not significantly impact the deadwood carbon stock ($p = 0.4041$). In contrast, decay status had a significant effect on deadwood carbon stock ($p = 0.0041$), as shown in Table 2. A paired sample *t*-test revealed a significant difference in deadwood carbon stock between solid deadwood

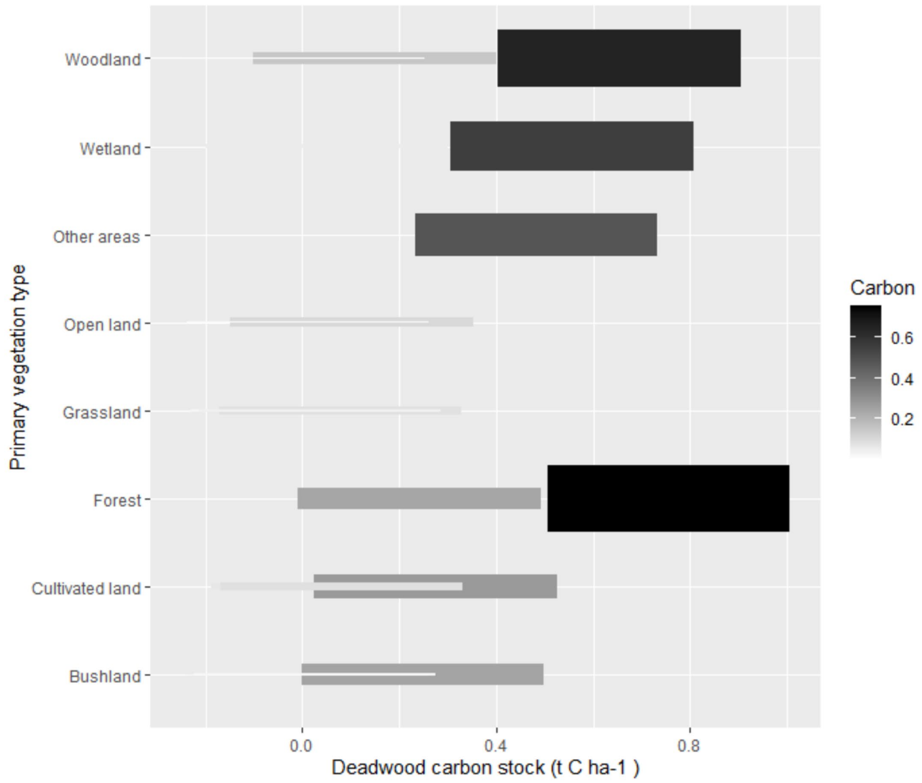

FIGURE 4
A heat map showing deadwood carbon stock distribution across different vegetation types. Deep color represents higher carbon stock values, slightly deep color represents median values, and lighter color represents lower values.

TABLE 2 ANOVA results for the effects of vegetation type and decay status on deadwood carbon stock.

Factor	Df	Sum square	Mean square	*F* value	Pr (>*F*)
Vegetation type	7	0.3185	0.0455	1.21	0.4041
Decay status	1	0.6598	0.6598	17.54	0.0041**
Residuals	7	0.2633	0.0376		

** $p < 0.05$ (Highly significant).

(mean = 0.462, SD = 0.287) and rotten deadwood (mean = 0.0497, SD = 0.0435; t (7) = −4.22, $p = 0.0039$). The highest deadwood carbon stocks (0.93 ± 0.00061 t C ha^{-1}) were obtained from solid deadwood found in forest, while the lowest deadwood carbon stock (0.004 ± 0.00037 t C ha^{-1}) was obtained from rotten deadwood found in grassland (Table 3). The estimated deadwood carbon stock across the primary vegetation contributed to 0.79% of total estimated carbon stocks generated from (Mauya et al., 2019) (Table 4).

3.2 Uncertainty estimates

Across different vegetation types, the associated deadwood carbon uncertainty estimates ranged from 0.002 to 0.34% with the highest estimates from cultivated land followed by other areas and the least from woodland (Figure 5). Based on deadwood decay status, uncertainty values ranged from 0.0008 to 0.28% whereby the highest uncertainty value (0.28%) was from rotten deadwood found in cultivated land and the lowest uncertainty value (0.0008%) was estimated from rotten deadwood found in woodland (Table 5).

4 Discussion

4.1 Deadwood carbon stock

The carbon sink potential of ecosystems, including the contribution of levels of woody decay, can vary depending on various factors such as vegetation type and management practices (Gogoi et al., 2022). The extended storage time of carbon within deadwood contributes to the overall stability and persistence of carbon storage in the ecosystem (Janisch and Harmon, 2002). The results showed that, forests and woodlands have higher deadwood carbon stocks likely due to the inherent characteristics of forests and woodlands, i.e., the accumulation of substantial amounts of woody biomass over time (McElhinny et al., 2005). A notable proportion of the deadwood in these ecosystems is composed of solid deadwood, which takes longer to decompose and maintains its structural integrity for a longer duration, as this contributes to a stable carbon stock compared to rotten deadwood. Along with this, active management practices implemented in these ecosystems, such as sustainable logging (Osone et al., 2016; Rozak et

TABLE 3 Deadwood carbon stock estimates based on decay status for each primary vegetation type.

Primary vegetation type	Decay status	Area (ha)	Weighted biomass (t ha^{-1})	Carbon stock (t C ha^{-1})
Bushland	Solid	7,608,200	0.79	0.373
	Rotten	7,608,200	0.05	0.025
Cultivated land	Solid	8,094,200	0.61	0.289
	Rotten	8,094,200	0.29	0.138
Forest	Solid	3,364,400	1.98	0.93
	Rotten	3,364,400	0.16	0.077
Grassland	Solid	8,835,900	0.33	0.154
	Rotten	8,835,900	0.008	0.004
Open land	Solid	234,200	0.23	0.107
	Rotten	234,200	0.15	0.007
Other areas	Solid	1,892,700	1.17	0.5
	Rotten	1,892,700	0.09	0.045
Wetland	Solid	1,162,600	1.15	0.544
	Rotten	1,162,600	0.12	0.059
Woodland	Solid	47,257,200	1.58	0.75
	Rotten	47,257,200	0.09	0.043

TABLE 4 Contribution of deadwood carbon stock to the total estimated carbon stock across each vegetation type.

Primary vegetation type	*[1]Deadwood carbon stock (t C ha^{-1})	*[2]Deadwood carbon stock (t C ha^{-1})	*[3]Total carbon stock (t C ha^{-1})	Estimated deadwood carbon stock (t C ha^{-1})	Contribution (%)
Bushland	5.4	0.36	87.4	0.39	0.45
Cultivated land	4.0	0.45	48.9	0.42	0.86
Forest	20.3	1.39	244.5	1.01	0.41
Grassland	0.73	0.17	15.0	0.16	1.07
Open land	1.3	0.11	9.7	0.11	1.13
Other areas	0.5	0.48	7.2	0.59	8.19
Wetlands	1.2	0.64	11.6	0.61	5.26
Woodland	3.5	0.89	91.7	0.80	0.87
Total	37.93	5.49	516	4.09	0.79

*[1 and 2]Values of deadwood carbon stock from Mauya et al. (2019), URT (2017) respectively. *[3] Values of total carbon stock from Mauya et al. (2019).

al., 2018) and selective tree harvesting (Pfeifer et al., 2015) support the accumulation of deadwood which is likely contributed to this observed pattern. However, the estimated carbon stock values are smaller when compared to other studies by Gurmessa et al. (2021), Pfeifer et al. (2015), this might be attributed to high occurrence of fire incidence and firewood collections in tropical dry forest and woodland (Tarimo et al., 2015).

Nevertheless, various studies have demonstrated that, other factors such as tree species composition (Kahl and Bauhus, 2014) and stand age (Pregitzer and Euskirchen, 2004) also play a significant role in influencing deadwood carbon stocks within these ecosystems. Furthermore, the disturbance regimes such as natural disasters or human-induced disturbances, can also affect the accumulation and availability of deadwood carbon stock in these ecosystems (Joshi and Singh, 2020). Also, results showed that, there was lower deadwood carbon stock in grasslands than other vegetation types which could be attributed to frequent disturbances such as grazing and fire as they limit the amount of deadwood that accumulates in grassland ecosystems. These findings are in line with the other study by Merganičová et al. (2012), who revealed that, deadwood carbon stocks in grassland were positively correlated with woody plant cover and negatively correlated with grazing intensity.

4.2 Uncertainty

The uncertainty analysis in this study provided valuable insights into the variability of carbon fluxes associated with deadwood decay, which is critical for improving the accuracy of national carbon accounting models (Garbarino et al., 2015; Harmon et al., 2013). The findings revealed that, uncertainty estimates for deadwood carbon stocks vary significantly across different vegetation types and decay status, with higher uncertainty observed in cultivated lands compared to

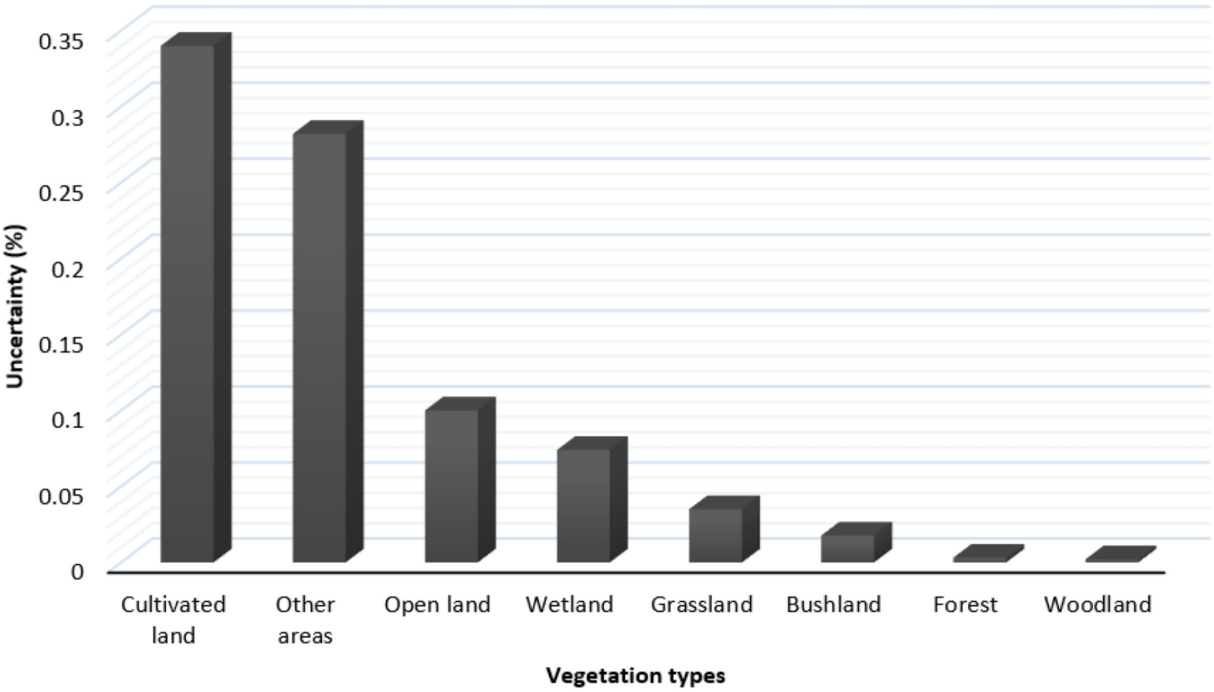

FIGURE 5
The associated deadwood carbon uncertainty estimates across different vegetation types.

TABLE 5 Uncertainty estimates based on decay status for each primary vegetation type.

Primary vegetation type	Decay status	Uncertainty (%)
Bushland	Solid	0.013
	Rotten	0.0047
Cultivated land	Solid	0.057
	Rotten	0.283
Forest	Solid	0.0016
	Rotten	0.0015
Grassland	Solid	0.020
	Rotten	0.015
Open land	Solid	0.084
	Rotten	0.016
Other areas	Solid	0.126
	Rotten	0.156
Wetland	Solid	0.046
	Rotten	0.028
Woodland	Solid	0.0012
	Rotten	0.0008

woodlands. This pattern highlights the influence of land-use practices and environmental conditions on deadwood dynamics (Merganičová et al., 2012). The highest uncertainty value from cultivated lands could be due to anthropogenic disturbances such as tillage, which introduce variability in deadwood accumulation and decomposition rates (Gross et al., 2022). In contrast, woodlands, with their more stable and predictable deadwood dynamics, show lower uncertainty, reflecting the consistent decay processes typical of natural forest ecosystems.

The findings also showed higher uncertainty values in carbon stock estimates of rotten deadwood compared to solid deadwood, which are consistent with other studies by Harmon et al. (2013), Hyvönen et al. (2007), Seibold et al. (2016). The higher uncertainty in rotten deadwood could be attributed to the inherent variability in decay rates, decomposition patterns, and spatial–temporal dynamics. As deadwood progresses through decomposition, its physical and chemical properties change, leading to greater heterogeneity in carbon content and distribution. This variability is further compounded by measurement limitations, as highlighted by Russell et al. (2015) who emphasize the difficulties in assessing carbon distribution and accessibility within rotten deadwood. These challenges are particularly pronounced in cultivated lands, where human activities and environmental conditions exacerbate the complexity of deadwood decay processes.

The results of this study have important implications for carbon stock assessments and climate change mitigation strategies. The relatively low uncertainty estimates in woodlands suggest that these ecosystems can serve as reliable benchmarks for carbon accounting. However, even in woodlands, continuous monitoring is necessary to account for natural disturbances such as storms, pests, and fires, which can alter deadwood dynamics (Seidl et al., 2014). Nevertheless, higher uncertainty estimates in cultivated and transitional areas underscores the need for improved sampling strategies and modelling approaches to account for human-induced variability. Integrating remote sensing technologies with field measurements could help capture the spatial heterogeneity of deadwood distribution, particularly in fragmented landscapes (Marchi, 2019). Additionally, long-term monitoring and model refinement are essential to better understand the temporal dynamics of deadwood carbon stocks and decay processes. By addressing these challenges, the accuracy of national greenhouse gas inventories can be enhanced, supporting more effective climate change mitigation efforts.

5 Conclusion

Incorporating decay status into national greenhouse gas inventory is crucial for improving the accuracy of deadwood carbon pool estimates and emissions reporting. This can significantly contribute to climate mitigation efforts, including REDD+ and Tanzania's National Determined Contributions (NDC) targets. This study also highlights the importance of adopting sustainable land management practices that prioritize the conservation and restoration of natural ecosystems, particularly forests and woodlands to enhance carbon storage potential. Further research is needed to better understand deadwood carbon emissions across different vegetation types with their levels of uncertainty.

Data availability statement

The data that supports the findings of this study are available from the corresponding author upon reasonable request from Tanzania Forest Service Agency (TFS).

Author contributions

SM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. DS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. EZ: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. BG: Data curation, Methodology, Conceptualization, Formal analysis, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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