INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 13, No. 6, p. 29-37, 2021
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Quantification of deadwood littered by *Acacia* spp. in semi-arid ecosystems of central Tanzania: The role of deadwood in biodiversity conservation

Elkana Hezron[*1,2], **Julius W Nyahongo**[2]

[1] *Department of Sustainable Agriculture, Biodiversity and Ecosystem Management, School of Life Sciences and Bioengineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania*

[2] *Department of Biology, College of Natural and Mathematical Sciences, The University of Dodoma, Dodoma, Tanzania*

Article published on June 30, 2021

Key words: Deadwood, *Acacia tortilis*, *Acacia nilotica*, Semi-arid ecosystems, Biodiversity

Abstract

Deadwood (DW) is an important carbon component for conservation and management of biodiversity resources. They are ubiquitous in many semi-arid ecosystems although its estimation is still posing lots of challenges. At Chimwaga woodland in Dodoma Region of Central Tanzania, seasonal quantification of DW produced by two *Acacia spp*. was done to evaluate the influence of each tree species, Dbh and canopy area on DW biomass and to determine their ecological role in conservation of semi-arid ecosystem. Both purposive and random sampling techniques were used in the course of a completely randomized design (CRD). Thirty trees from each species of *Acacia tortilis* and *Acacia nilotica* were studied. Results portray that DW biomass was significantly higher ($P < 0.05$) in the dry season than in the rain season whereby *A. tortilis* produced 669.0 ± 135.90kg DM/ha (dry season) and only 74.3 ± 135.90kg DM/ha (rain season) while *A. nilotica* produced 426.1 ± 135.90kg DM/ha (dry season) and 36.5 ± 135.90kg DM/ha (rain season). DW biomass did not correlate significantly ($P > 0.05$) with Dbh and canopy area. Inter-specific interactions were encountered from experimental areas where DW was littered that facilitated ecosystem balance in semi-arid areas. This information is important for estimating amount of dead wood biomass required to be retained in the forest provided that, at the expense of ecology, they are refuge for arthropods, fungi, bryophytes and other important soil microbes representing primary components of Biodiversity in semi-arid ecosystems.

***Corresponding Author:** Elkana Hezron ✉ elkanahezron@yahoo.com

Introduction

Natural treasures and heritage such as those of semi-arid areas rich in deadwood (DW) materials are rapidly utilized and depleted by living organisms globally while facing an extinction rate of about 100-1000 times compared to the rate before 150,000 years ago of human life time (Baharul & Khan, 2010). Thousands of organisms depend on DW as an important key for biodiversity in forest ecosystems (Harmon & Sexton, 1996; Pyle & Brown, 1999). Africa and other continents such as Australia and America are comprised of such resources at large although they are faced with many challenges from anthropogenic activities (IUCN, 2017). Tanzania in East Africa is one among rich countries in terms of natural resources and biodiversity comprising semi-arid woodlands (URT, 2014). Vast of Ecological, environmental and botanical studies have been done purposely to determine total area covered by forests, identify and estimate species diversity, abundance and distribution (Malimbwi & Zahabu, 2014; Monela, Chamshama, Mwaipopo, & Gamassa, 2005). Other studies are done to assess ecosystem goods and services obtained from these resources (Dharani, 2006; FAO, 2010; Monela *et al.*, 2005; Sharam, Sinclair, Turkington, & Jacob, 2009). In disparity to the reported information, studies on DW production that estimate the biomass in semi-arid areas are scarce. Fewer research reports are available to describe the ecological importance contributed by DW and their role in biodiversity conservation for prevalence of savanna dry lands as well as sustainable use of forest products in semi-arid regions.

Earlier than 2007, many communities around the world considered DW as of less significant in the ecosystems (Stachura, Bobiec, Obidziñski, Oklejewicz, & Wolkowycki, 2007). These resources were regarded as uneconomical, obstacles to silviculture and reforestation that were reflected to a cause of abiotic disturbance that threatened the health of terrestrial ecosystems by catching fire easily (Pfeifer *et al.*, 2015; Thomas, 2002; Travaglini *et al.*, 2007; Travaglini & Chirici, 2006). Additionally, stumps from dead trees seemed to be source of injuries that endangered the public safety (Peterken, 1996; Thomas, 2002). Dead Wood pieces and stumps are cleared from forests as a sanitary strategy (WWF, 2004). Collections of wood fuels increased from 243.3 million m^3 (in 1990) to 313.9 million m^3 (in 2005) in the Eastern and Southern African forests (Monjane, 2009). These actions lowered the quantity of DW and their ecological significance in the ecosystems (Travaglini *et al.*, 2007). It is further reported that there were a stable quantity of harvestable DW produced from 1992/93 to 1995/96 regardless of partial variation from year to year in the African woodlands as indicated in Table 1 (Collins, 1977; Malaisse, Alexandre, Freson, Goffinet, & Malaisse-Mousset, 1972; Malaisse, Freson, Goffinet, & Malaisse-Mousset, 1975; Shackleton, 1998).

Table 1. Yearly harvestable DW biomass produced in different woodlands of African countries.

Year	Type of woodland	Biomass (kg /ha)	Country
1972	Miombo Woodlands	4400.0	Congo DRC
1977	Savanna woodlands	682.0	Guinea
1992/93	Semi-arid woodlands	387.8	South Africa
1993/94	Semi-arid woodlands	270.4	South Africa
1994/95	Semi-arid woodlands	353.6	South Africa
1995/96	Semi-arid woodlands	211.7	South Africa

Source: Malaisse, Freson, Goffinet, & Malaisse-Mousset (1972), Collins (1977) & Shackleton (1998)

In recent years since 2000 up to date, conservationists have become alarmed about the role of DW in the natural ecosystems (Rondeux & Sanchez, 2009; MCPFE, 2002; Humphrey *et al.*, 2004; Schuck, Meyer, Menke, Lier, & Lindner, 2004). Leaders in the developed and developing countries are encouraged by the WWF to call foresters, environmentalists, agriculturists and ecologists to conserve biodiversity by increasing DW in the forests to 20-30 m^3/ha by 2030 (WWF, 2004; Marage & Lemperiere, 2005; Zielonka, 2006; Vandekerkhove *et al.*, 2009; Humphrey & Bailey, 2012).

It is reported that the available information on DW production is limited to total harvestable and standing DW with scarce data on the biomass produced by DW in semi-arid ecosystems under the influence of natural factors (Malaisse *et al.*, 1972; Collins, 1977; Shackleton, 1998; Chojnacky & Heath, 2002; WWF, 2004).

Hence, the study aimed to (1) quantify the amount of DW biomass produced by *Acacia spp*. during dry and rain seasons, (2) evaluate the influence of each tree species, Dbh and canopy area on DW biomass and (3) to determine the ecological role of DW in conserving biodiversity of semi-arid ecosystem through provision of nutrients to decomposers.

Materials and methods

Study area

This study was done around the University of Dodoma at Chimwaga Complex site. The area is characterized by semi-arid type of climate that dominates large part of central Tanzania. The site is located between 35°47'37.44" E longitude to 6°12'27.06"S latitude and 35°48'06.84" E longitude to 6°12'37.95" S latitude as indicated in Fig. 1. Its climate is characterized by an average rainfall of 570mm annually while the yearly maximum and minimum temperatures are 31°C and 18°C, respectively.

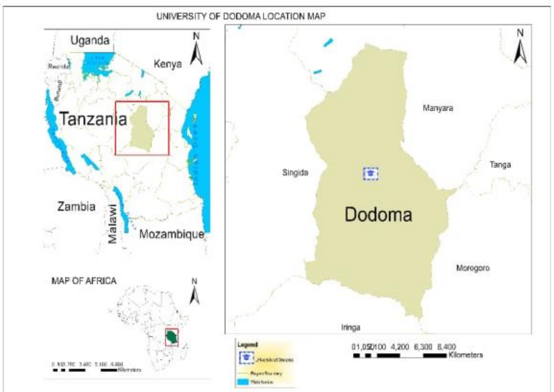

Fig. 1. Map Showing Chimwaga woodland around University of Dodoma, Tanzania.

Its vegetation is of "bush" type covered by Acacia-Commiphora woodland. Its soil characteristics are of sandy-loamy soils. The dominant communities of Gogo tribes in the nearby villages are engaged in social-economic activities such as agriculture, animal husbandry as well as small scale business for sustainable family expenditure though urbanization rate is relatively high replacing traditional agriculture.

Data collection

The study involved both purposive and random sampling techniques whereby, Chimwaga forest patch was sampled purposively from all other forest patches of the semi-arid woodland around the University of Dodoma due to its less interruption from anthropogenic activities. Forest surveys were conducted randomly whereby completely randomized design (CRD) was adopted. A sample of 60 trees were selected by using random numbers generated from a scientific calculator (fx-991-CASIO) from a total of 120 trees of *A. tortilis* and *A. nilotica* populations that were numbered in the semi-arid woodland of Chimwaga Complex. Canopy cover for each sampled tree was measured by using a range finder in preference of a tape measure as described by the NAFORMA, (NAFORMA, 2015; Cunningham, 2001).

Littered dead stems and branches were collected via hand picking method under each selected canopy area of individual *Acacia spp*. In-situ measurement of DW was done by using an electronic balance (CAMRY Model: EK 3131). The overall fresh weight of collected DW was recorded as W_1. DW sub-samples were taken from the overall DW pieces collected. Their fresh weight were measured and recorded as W_2. The sub-samples were packed in the A4 envelopes and oven dried at 65°C for 24 hours in the laboratory. A dry weight was measured and recorded as W_3. Total dry weight (W_T) was finally computed by using equation 1 as described by Pearson, Walker and Brown (2005),

$$W_T = \frac{W_1 W_3}{W_2} \quad \text{.. 1}$$

Time frame and season configuration for data collection

Data were collected in five months that were sandwiched between dry season and rain seasons as indicated in table 2.

Data analysis

Data were categorized and ordered by using excel spread sheet. They were finally analyzed by SAS and SPSS for windows version 16 and 21, respectively. Results were summarized in form of tables and graphs. Means were reported as Mean ± Standard Error. Comparison of the means was computed using One way ANOVA and Pearson's correlation. In a case where P-value; $P < 0.05$, the influence was considered significant.

Table 2. Seasonal variation in climatic conditions of Dodoma Region.

Meteorological Parameters	Months					
	Dry season			Rain season		
	Dec, 2016	Jan, 2017	Feb week 2, 2017	Feb week 4, 2017	Mar, 2017	Apr, 2017
Temperature (°C)	25.5	25.3	24.5	23.5	23.4	23.1
Rainfall (mm)	7.6	71.6	68.1	132.9	112.2	9.4
Wind speed (m/s)	8.7	6.2	6	7	4	8

Source: Tanzania Meteorological Agency (TMA), Dodoma, 2017 (Unpublished data).

Results and discussion

Effect of Species and Season on Deadwood production

General observation after analysis depict that the overall means of DW biomass produced by both *A. tortilis* and *A. nilotica* corresponded with 371.6 ± 96.1kg DM/ha and 231.3 ± 96.1kg DM/ha, respectively. The findings revealed that DW biomass was significantly ($P < 0.05$) higher in the dry season than in the rain season as per progressive decrease in deadwood production with respect to time as shown in Fig. 2. One-way ANOVA analysis shows that there was no significant ($P > 0.05$) variation in DW biomass between *A. tortilis* and *A. nilotica* during the rain season, while the differences between these two species were significant ($P < 0.05$) during the dry season as summarized in Table 3. The possible reason for this variation was a rhythmic climatic condition as shown in Table 2. During rain season, plant produces new branches and leaves enriched with chlorophyll pigments and new living cells to enhance trapping of sunlight energy and water uptake that facilitate photosynthesis process. From this observation, newly sprouted leaves and branches are used to produce more starch as food stock for the plant during dry season. On the onset of dry season, many leaves and branches would suggest more loss of water and stored food due to adverse climatic condition than in the rain season. Thus, plants do shade them off to reduce overutilization of water and stored food resources. This finding support other studies conducted in semi-arid and other areas such as East African savanna woodlands (Dharani, 2006; Stevenson, 2002). Worldwide Wildlife Fund (WWF), (2004) and Merganičová, Merganič, Svoboda, Bače, & Šebeň, (2012) reported that seasonal variation of climatic condition specifically temperature, rainfall and wind lead to high DW biomass in the dry season and low DW biomass during rainy season.

Table 3. Seasonal quantity of DW biomass produced by *A. tortilis* and *A. nilotica* in Chimwaga Forest patch of central Tanzania.

Species	Season	Deadwood Biomass (±SE) (kg DM/ha)
A. nilotica	Dry	426.1 ± 135.90[a]
	Rain	36.5 ± 135.90[bc]
A. tortilis	Dry	669.0 ± 135.90[a]
	Rain	74.3 ± 135.90[c]
Significant effect of:		
Species		n.s (F=1.07; d.f=1; P=0.303)
Season		*** (F=13.11; d.f=1; P=0.0004)
Species*Season		n.s (F=0.57; d.f=1; P=0.452)

[a, b, c]Column means with different superscripts are significantly different (*P<0.05*), n.s (the effect is not significant, *P>0.05*); *** (*P<0.001*); SE (Standard error)

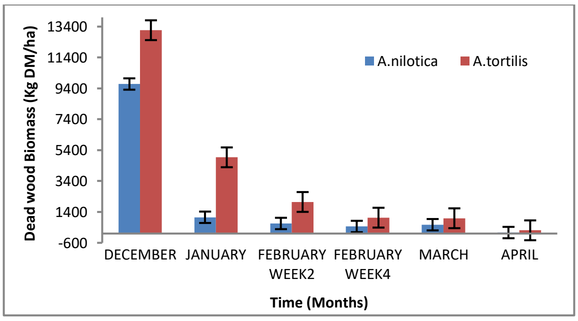

Fig. 2. A graph showing DW biomass produced in monthly basis for all seasons.

Moreover, variation in DW biomass between *A. nilotica* and *A. tortilis* during dry season was influenced by their structural, physiological and evolutionary differences as described by Fagg & Greaves (1990). *A. nilotica* evolved along river Nile in Africa and it is inhabited around semi-arid and desert areas (Dharani, 2006; Fagg & Greaves, 1990). Its wood and barks are tough compared to those of *A. tortilis* (Fagg & Greaves, 1990). Hence, it is able to withstand extreme temperatures and low rainfall resulting to low DW production compared to *A. tortilis* which inhabit areas of sand dunes, rocky scarps and alluvial valley bottoms (Dharani, 2006).

However, they are all drought resistant species. This observation suggests that DW from *A. tortilis* might be potential source of carbon and other inorganic soil nutrients in semi-arid woodlands and forests after decomposition process has taken place. Similar observation was described by Barbosa-Silva & Vasconcellos (2019).

Effect of species' Dbh and canopy area on DW biomass

The DW biomass did not correlate significantly ($P > 0.05$) with Dbh and canopy area in both rain and dry seasons as shown in Table 4 and Table 5. This may suggest that Dbh and canopy area had no effect on the quantity of DW produced by *Acacia spp*. DW could be higher or lower regardless of the tree canopy size and Dbh. The findings from the analysis of canopy size and Dbh of sampled trees, suggest unexpected results since it was assumed that the larger the canopy area and Dbh, the higher the DW production was expected. However, the results suggest opposite.

Table 4. Correlation effect of tree Canopy cover on DW production.

Species	CA (±SE)	Season	DWBM (±SE) (kg DM/ha)	Pearson's correlation 'r'	P-value
A. nilotica	47.9 ± 6.14^{a}	Dry	426.1 ± 135.9^{c}	-0.112	0.555
		Rain	36.5 ± 135.9^{de}	0.119	0.530
A. tortilis	87.0 ± 6.14^{b}	Dry	669.0 ± 135.9^{c}	-0.408	0.025
		Rain	74.3 ± 135.9^{e}	-0.263	0.160
Effect of: Canopy Area				n.s	

$^{a, b, c, d, e}$ Column means with different superscripts along the same column are significantly different ($P<0.05$); CA is canopy area; Dbh is diameter at breast height; DWBM is deadwood biomass; n.s (not significant, $P>0.05$)

Table 5. Correlation effect of tree Dbh on DW production.

Species	Dbh (±SE)	Season	DWBM (±SE) (kg DM/ha)	Pearson's correlation 'r'	P-value
A. nilotica	16.8 ± 1.04^{a}	Dry	426.1 ± 135.9^{c}	-0.015	0.939
		Rain	36.5 ± 135.9^{de}	-0.220	0.242
A. tortilis	24.8 ± 1.04^{b}	Dry	669.0 ± 135.9^{c}	-0.56	0.770
		Rain	74.3 ± 135.9^{e}	0.006	0.975
Effect of: Dbh				n.s	

$^{a, b, c, d, e}$ Column means with different superscripts along the same column are significantly different ($P<0.05$); CA is canopy area; Dbh is diameter at breast height; DWBM is deadwood biomass; n.s (not significant, $P>0.05$)

Roles of DW in semi-arid ecosystem and Biodiversity Conservation

DW pieces were studied and observations from experimental sites show that they provide a very potential ecological support to biodiversity as follows,

Habitats

Some arthropods were found on DW branches using them as their habitat and niches as shown in Fig. 3 and Fig. 4. These included small black ants (*Monomorium minimum*), large black ants (*Pachycondyla analis*), millipedes (*Anadenobolus monilicornis*), centipedes (*Scolopendra singulata*) and termites (*Cryptotermes cavifrons* and *Macrotermes bellicosus*). The information is supported by a hypothesis put forward by WWF (2004), Wu, Guan, Han, Zhang, & Jin (2005) who hypothesized that "presence of deadwood in any ecosystem contributes to sustainable continuation and conservation of important natural habitats to a wide range of living organisms".

(a) **(b)**

Fig. 3. (a) Small black ants (*Monomorium minimum*) (b) Large black ants (*Pachycondyla analis*) utilize burrows and the Deadwood leftovers as their nesting habitats.

(a) **(b)**

Fig. 4. (a) Centipedes (*Scolopendra singulata*) and (b) Termites (*Macrotermes bellicosus*) utilize the decomposing DW as their nesting place.

Inter-specific interaction

Fungal species were found to have an association with algae species as well as littered DW branches forming Lichens over DW barks and still yet decomposition by termites took over regardless of lichens availability especially during the rain season. Moreover, the mosses show an interaction with termites having an ability to grow in presence of termites mounds built in areas with DW materials as indicated in Fig 5. Similar observation was reported by Barbosa-Silva & Vasconcellos (2019) who suggested that termites can utilize lichens as a supplemental source of nutrients with effect to consumption of wooden materials in semi-arid areas of Northern Brazil.

(a) **(b)**

Fig. 5. (a) Inter-specific interaction between termites and Lichens.
(b) Inter-specific interaction between termites and Mosses.

Food to Wild animals

The DW itself was utilized by termites as their important food sources. Presence of black ants, millipedes and termites was potential source of feed for centipedes and reptiles especially Jackson's chameleon (*Chameleo jacksonii*) that was found around the areas with DW materials as depicted in Fig 6.

(a) **(b)**

Fig. 6. (a) Jackson's chameleon and (b) Termites utilize feed sources around their niches in presence of Deadwood material.

The availability of DW offering habitats to a wide range of organisms like mosses, lichens, arthropods and reptiles enhances the inter-specific interactions. It facilitates existence of food chains and food webs that maintain the ecosystem structure and stability. Similar observations were described by Stevenson, (2002) as well as Hodge & Peterken, (1998) who suggested that in natural temperate and boreal forests, DW gives important habitat for small vertebrates and invertebrates. Lichens, bryophytes, polypores and other fungal species obtain niches, habitats and nutrients under the ecosystem interaction (Laudenslayer, Shea, Valentine, Weatherspoon & Lisle, 2002; Svensson, 2013).

Conclusion and recommendations

DW is important to biodiversity conservation that needs to be given special attention and consideration in a wide range of aspects for sustainable forest resource management, environmental protection and tourism. It is recently regarded that a forest is natural if there are enough kinds of DW. Researchers and governments are now surveying in forests to find out the extent to which DW should be available in a natural forest as a reference and management scale

In addition to that DW produced by *Acacia tortilis* and *Acacia nilotica* need to be protected from being exploited (extremely harvested) in semi-arid ecosystems. It is necessary to consider DW as a potential habitat and source of nutrients for macro and micro-organisms. To enhance habitat for more exacting species, the provision of DW should be targeted where it will provide added value to existing habitat, expand habitat area and improve linkage between habitats.

Acknowledgement

I owe my special gratitude to all people who have participated in giving their contributions for successful completion of this piece of work. Fore thanks are given to the University of Dodoma for admission. Many thanks are given to the Department of Biology for their potential efforts; time, encouragement and advice. Further thanks are forwarded to the Nelson Mandela African Institution of Science and Technology for technical and space (office) assistance during manuscript preparation.

Declarations of interest: None

References

Baharul C, Khan ML. 2010. Conservation and Management of Endangered Plant species. India: Global Science Books.

Barbosa-Silva AM, Vasconcellos A. 2019. Consumption Rate of Lichens by *Constrictotermes cyphergaster* (Isoptera): Effects of C, N, and P Contents and Ratios, *Insects*, DOI: 10.3390/ insects1001002

Chojnacky DC, Heath LS. 2002. Estimating down dead wood from FIA forest inventory variables in Maine, ELSEVIER-Environmental pollution, USA

Collins NM. 1977. Vegetation and litter production in southern Guinea savanna. Plant Molecular Biology **28(2),** 163-175.

Cunningham AB. 2001. Applied Ethnobotany; "People, wild plant use and Conservation", Earthcam from routledge, UK & USA

Dharani N. 2006. Field guide to Acacias of East Africa. Nairobi-Kenya: Struik Publishers.

Fagg CW, Greaves A. 1990. *Acacia nilotica* 18691988, CABI/OFI, Annotated bibliography No. F42. CAB International, Wallingford, Oxon, UK 77 p.

FAO. 2010. Global forest resources assessment (FRA) Main report *The Forest Resources Assessment Programme* (pp. 378). Rome: Food and Agriculture Organization of the United Nations.

Harmon ME, Sexton J. 1996. Guidelines for Measurements of Woody Detritus in Forest Ecosystems. U.S. LTER Publication **20,** 79.

Hodge SJ, Peterken GF. 1998. "Deadwood in British Forests: Priorities and a Strategy." Forestry **71(2),** 99-112. doi:10.1093/forestry/71.2.99.

Humphrey J, Bailey S. 2012. Managing Deadwood in Forests and Woodlands: Practice Guide. Edinburgh: Forestry Commission.

Humphrey JW, Sippola AL, Lemperiere G, Dodelin B, Alexander KNA, Butler JE. 2004. Deadwood as an indicator of biodiversity in European forests: from theory to operational guidance. EFI Proceedings **51,** 193-206

IUCN. 2017. Table 1: Numbers of threatened species by major groups of organisms (1996–2017). In I. U. f. C. o. Nature (Ed.), (pp. 1-2): IUCN 2017.

Laudenslayer WFJr, Shea PJ, Valentine BE, Weatherspoon CP, Lisle TE. 2002. Proceedings of the symposium on the ecology and management of dead wood in western forests: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-181 p. 949

Malaisse F, Alexandre R, Freson R, Goffinet G, Malaisse-Mousset M. 1972. *The miombo ecosystem: a preliminary study* United States of America: Georgia Press.

Malaisse F, Freson R, Goffinet G, Malaisse-Mousset M. 1975. Litter fall and litter breakdown in miombo. Heidelberg: Springer.

Malimbwi RE, Zahabu E. 2014. NAFORMA Process and Biophysical Results. Morgoro-Tanzania: Sokoine University of Agriculture.

Marage D, Lemperiere G. 2005. The management of snags: A comparison in managed and unmanaged ancient forests of the Southern French Alps. Annals of Forest Science **62(2),** 135-142

MCPFE. 2002. Improved Pan-European indicators for sustainable forest management as adopted by the MCPFE Expert Level Meeting 2002, Available from http://www.mcpfe.org/system/files/u1/Vienna_Improved_Indicators.pdf

Merganičová K, Merganič J, Svoboda M, Bače R, Šebeň V. 2012. Deadwoodin Forest Ecosystems, Forest Ecosystems - More than Just Trees, Dr Juan A. Blanco (Ed.), ISBN: 978-953-51- 0202-1, InTech,

Monela GC, Chamshama SAO, Mwaipopo R, Gamassa DM. 2005. A Study on the Social, Economic and Environmental Impacts of Forest Landscape Restoration in Shinyanga Region, Tanzania (pp. xvii-205). Dar-es-Salaam, Tanzania: Forestry and Beekeeping Division of the Ministry of Natural Resources and Tourism, of Tanzania, and IUCN.

Monjane M. 2009. Eastern and Southern Africa Forest and Woodlands Situational Analysis. Zambia: IUCN Eastern and Southern Africa regional office.

NAFORMA. 2015. Field manual Biophysical survey, Ministry of Natural Resources and Tourism-forestry and beekeeping division, Tanzania

Pearson T, Walker S, Brown S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. World Bank

Peterken GF. 1996. Natural woodland. Ecology and conservation in northern temperate regions (Vol. 4). Cambridge University-U.K: Cambridge University Press.

Peterken GF. 1996. Natural woodland: Ecology and conservation in northern temperate regions. Cambridge, Cambridge University Press

Pfeifer M, Lefebvre V, Turner E, Cusack J, Khoo MS, Chey VK, . . . Ewers RM. 2015. Deadwood biomass: an under-estimated carbon stock in degraded tropical forests. IOP Publishing house 1-11. doi: 10.1088/1748-9326/10/4/044019

Pyle C, Brown MM. 1999. Heterogeneity of wood decay classes within hardwood logs. Forest Ecology and Management **114(2-3),** 253-259. doi: 10.1016/S0378-1127(98)00356-9

Rondeux J, Sanchez C. 2009. Review of indicators and field methods for monitoring biodiversity within national forest inventories. Core variable: Deadwood. Environmental Monitoring and Assessment **164(1-4),** 617-630

Schuck A, Meyer P, Menke N, Lier M, Lindner M. 2004. Forest biodiversity indicator: dead wood - a proposed approach towards operationalising the MCPFE indicator. EFI-Proceedings **51,** 49-77

Shackleton CM. 1998. Annual production of harvestable deadwood in semi-arid savannas, South Africa. ELSEVIER-Wits Rural Facility & Centre for African Ecology **112,** 139-144.

Sharam GJ, Sinclair ARE, Turkington R, Jacob AL. 2009. The savanna tree Acacia polyacantha facilitates the establishment of riparian forests in Serengeti National Park Tanzania Journal of Tropical Ecology Cambridge University Press, U.K **25(1),** 31-40. doi: 10.1017/S0266467408005683

Stachura K, Bobiec A, Obidziñski A, Oklejewicz K, Wolkowycki D. 2007. Old trees and decaying wood In forest ecosystems of Poland "Old Wood". A toolkit for participants.

Stevenson AW. 2002. Life in the deadwood; A guide to managing deadwood in forestry commission Forest Enterprise – Environment & Communications, Edinburgh.

Svensson M. 2013. Occurrence Patterns of Dead Wood and Wood-dependent Lichens in Managed Boreal Forest Landscapes, Swedish University of Agricultural Sciences, Uppsala-Sweden.

Thomas JW. 2002. Dead Wood: from Forester's Bane to Environmental Boom. Paper presented at the Ecology and Management of Dead Wood in Western Forests, Reno, Nevada. Technical Report retrieved from

Travaglini D, Chirici G. 2006. Forest BIOTA project. Forest Biodiversity Test phase Assessments: Deadwood assessment (pp. 1-20).

Travaglini D, Barbati A, Chirici G, Lombardi F, Marchetti M, Corona P. 2007. ForestBIOTA data on deadwood monitoring in Europe. Official Journal of the Societa Botanica Italiana **141(2),** 222-230.

URT. 2014. Fifth National Report on the Implementation of the Conventionon Biological Diversity. Dar es Salaam: Vice President's Office, Division of Environment.

Vandekerkhove K, Keersmaeker De L, Menke N, Meyer P, Verschelde P. 2009. When nature takes over from man: Dead wood accumulation in previously managed oak and beech woodlands in North-western and Central Europe, Forest Ecology and Management **258,** 425-435

Wu J, Guan D, Han S, Zhang M, Jin C. 2005. "Ecological Functions of Coarse Woody Debris in Forest Ecosystem", Journal of Forestry Research **16(3),** 247-52.

WWF. 2004. Living forests: The importance of veteran trees and deadwood to biodiversity. Gland, Switzerland: World Wide Fund for Nature

Zielonka T. 2006. Quantity and decay stages of coarse woody debris in old-growth subalpine spruce stands of the western Carpathians, Poland, Canadian Journal of Forest Research **36,** 2614-2622.