Short Communication
pISSN: 2288-9744, eISSN: 2288-9752
Journal of Forest and Environmental Science
Vol. 35, No. 3, pp. 205-211, September, 2019
https://doi.org/10.7747/JFES.2019.35.3.205

JFES
Journal of Forest and Environmental Science

Assessment of Coarse Woody Debris in Gallery Forest in the Bombo-Lumene Reserve (Democratic Republic of Congo)

Butoto Imani wa Rusaati[1,2], Sung-Hyun Joo[1], Gi-Yun Yun[1], Joowon Park[1], Masumbuko Ndabaga Cephas[3] and Jun-Won Kang[1,*]

[1]*School of Forest Sciences and Landscape Architecture, College of Agriculture and Life Sciences, Kyungpook National University, Daegu 41566, Republic of Korea*
[2]*Natural Sciences Research Center(CRSN/Lwiro), DS Bukavu, Democratic Republic of Congo*
[3]*Depatment of Biology, Official University of Bukavu, BP 570 Bukavu, Democratic Republic of Congo*

Abstract

The objective of this research was to assess the amount of carbon stock of coarse woody debris (CWD) in Bombo-Lumene Reserve. Data on lying CWD was collected on 35 circular sampling plots using Line Intersect Sampling (LIS) method. A total of 230 samples CWD (≥10 cm diameter) were inventoried. The mean carbon stocks of CWD was 29.48 Mg C ha^{-1}, ranging from 4.32 to 73.54 Mg C ha^{-1}. The CWD carbon stocks displayed a wide range of variation in decay states. The allocation of CWD among the decay class of all the CWD samples reveals that the most important classes were class 1 and class 3 with 323.66 and 321.96 Mg C ha^{-1}, followed by class 4 with 264.56 and the last one was class 2 with 121.72 Mg C ha^{-1}. The results suggested that the dead wood component is important in carbon sequestration and should be taken into consideration for quantification of carbon stocks not only in Bombo- Lumene Reserve, but in all forest ecosystems in the Democratic Republic of Congo.

Key Words: Bombo-Lumene reserve, carbon stocks, coarse woody debris (CWD), Democratic Republic of Congo, line intersect sampling (LIS)

Introduction

Coarse woody debris (CWD) plays an important role in forest ecosystems (Yan et al. 2006; Fukasawa 2012; Herrmann et al. 2015). It contributes to carbon and nutrient cycling as well as provides habitats for many forest organisms including animals, plants, insects and microbes (Stares et al. 2018). The CWD is generally known as dead and downed wood such as snags, logs, stumps and logging residues. It also includes large dead branches and large portions of wood found in forest soil. CWD is typically created by human interventions and natural disturbances such as wildfire, floods, windstorms, diseases and insect infestations (Hagan and Grove 1999). In addition, environmental conditions, including vegetation type, moisture content, heterotroph activity and stage of succession significantly contribute to transmission of the CWD (Mccay et al. 2002; Teissier du Cros and Lopez 2009; Paletto et al. 2012; Tavankar et al. 2017; Yuan et al. 2017).

The Intergovernmental Panel on Climate Change

Received: January 21, 2019. Revised: July 10, 2019. Accepted: August 5, 2019.

Corresponding author: Jun-Won Kang

School of Forest Sciences and Landscape Architecture, College of Agriculture and Life Sciences, Kyungpook National University, Daegu 41566, Republic of Korea
Tel: 82-53-950-5748, Fax: 82-53-950-6708, E-mail: jwkang15@knu.ac.kr

(IPCC) guideline (2006) defines five carbon pools including living aboveground biomass, living belowground biomass, deadwood, litter and soil organic matter (SOM) in the terrestrial ecosystem which is the third largest global carbon pool over the ocean and geological carbon pool (Penman et al. 2003; Simon 2006; de Madron et al. 2011; Assefa et al. 2013). The forest ecosystems sequester and store more carbon per unit area among all terrestrial ecosystems (Dey et al. 2014; Kim et al. 2018) and the dead wood (CWD) represents one of the major carbon pools in natural forest ecosystems (Chao et al. 2008; Merganičová and Merganič 2010). It is considered a major component of the Forest Resource Inventory (FRI) (Taylor 1997; Harmon et al. 2011). The importance of dead wood (CWD) in the forest can be evaluated by the quantity that is influenced by the mortality of tree and decomposition rate, but also on its dispersion in terms of dimension, stems quantity, decomposition conditions, tree species, age, position, and a special organization (Kraigher et al. 2002). Therefore, estimating the quantity of CWD and the carbon stocks in CWD is crucial to understand forest ecosystems and their structure (Baker et al. 2007; Fravolini et al. 2016).

Muller and Liu (1991) estimated the mass of CWD from 22 to 49 Mg ha^{-1} in North American temperate deciduous forests, depending on stand age and productivity. Sato (2010), also, quantified the mass and inputs of CWD in two old-growth lucidophyllous forests in southwestern Japan and the CWD mass ranged from 20.77 to 36.85 Mg ha^{-1}.

Bombo-Lumene is a reserve in the Democratic Republic of Congo close to the capital city Kinshasa. It is an ecologically important reserve since where is made up of open and wooded savannas interspersed by tropical gallery forests along its rivers as well as small forest patches. Recently, many studies estimating CWD mass and density loss have emphasized the ecological roles of CWD in the world (Keller et al. 2004; Maraseni and Mitchell 2016; Silva et al. 2016; Netto et al. 2018). However, little information is available concerning the carbon stock of CWD in the Democratic Republic of Congo. Thus, the quantification of CWD and its carbon stocks in Bombo- Lumene Reserve could provide fundamental information to manage and protect gallery forests as well as all Congolese's forests.

Materials and Methods

Study site

Sampling was achieved in Bombo- Lumene Domain and Reserve (Democratic Republic of Congo), located at the east side of Kinshasa town, precisely at the edge of the urban- rural commune of Maluku, around 130 km from the city center (Habiyaremye et al. 2011), and comprised between 4° 20' and 5° 80' south latitude, 15° 50' and 16° 20' of east longitude, on altitude average of 600 m from the sea level (Milau et al. 2016) (Fig. 1).

Created through the ministerial decree N° 07 of February 10, 1968, as regards the part "domain" and 1976 for part "Reserve", with an objective to promote conservation and sustainable use of natural resources (Vermeulen and Lanata 2006). It is under control of

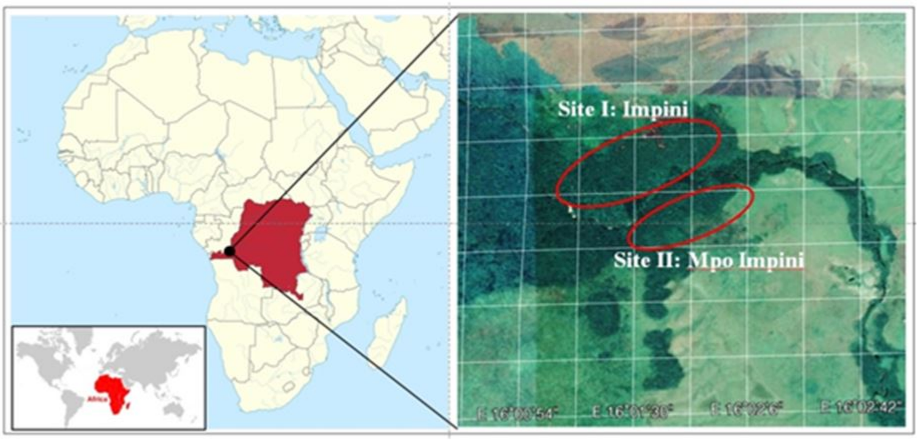

Fig. 1. Localization of studying area.

'Institut Congolais pour la Conservation de la Nature' (ICCN) (Moyene 2008). Bombo-Lumene Domain and Reserve cover an area of 350,000 ha and is subdivided into two groups: domain and Reserve. The studied area presents a climate, which, at regional level, belongs to the humid tropical climate of type AW4 according to the classification of KOPPEN. The mean annual temperature prevailing there is 24.8°C, while the annual precipitation average is 1549 mm (Kalambay et al. 2016).

The area includes a range of vegetation characterized by savannah (UICN/PACO 2010), punctuated by slits caused by continuous runoff and multiple riparian branches, the main flow into Bombo, Lumene and Lufimi. The first two having given their names to the site (Kayumba et al. 2015). These crevices and runoffs are covered by galleries forest with the largest tree species are *Gilbertiodendron dewevrei* (Caesalpinaceae), *Entandrophragme angolense* (Meliaceae), *Guibortia demeusei* (Caesalpinaceae) and *Uapaca guineensis* (Phyllanthaceae) (Inogwabini et al. 2006). The soil has an average particle size distribution of about 3.4% clay, 5.6% silt and 91% sand (Milau et al. 2016).

Experimental design

In July 2018, 35 circular plots were randomly established and surveyed along Lumene river. In each plot, three transect segments with 20m each one were laid out radiating from a central point. The orientation of segment 1 was selected uniformly random perpendicular to the direction of water flow, and segments 2 and 3 were oriented at ± 120° of the segment 1. The quantity of CWD was inventoried in the field using Line Intersects Sampling (LIS) method (Van Wagner 1968). It implies that all the objects intersected by line are included in the sample (Kangas and Maltamo 2006). The plots were distributed on both sides of the Lumene river in two sites as follows: Mpo Impini site sampled with 22 plots and Impini site that included anthropogenic disturbance with 13 plots. A total 35 sampling plots included 230 fallen coarse woody debris ≥10 cm. The plots were distributed in Mpo Impini (site 1) with 155 samples and Impini (site 2) with 75 samples recorded. For every tailed piece, transect diameter and decay state were measured. A particle of downed woody was included in the sampling if the small end measured 10 cm in diameter or greater, was not attached to the living tree, and lying on the floor at angles ≤45°. The volume of CWD was calculated using De Vries's formula:

$$V\ (m^3\ ha^{-1}) = ((\Pi^2/8\ L)\ \sum di^2) \times 10{,}000\ m^2\ ha^{-1}$$

Where V=volume per unit area; L=transect line's length; di=CWD diameter of each piece at the line intersection point (Böhl and Brändli 2007; Monfils et al. 2009; Teissier du Cros and Lopez 2009; Ifo et al. 2015).

Various decay class systems are used to classify CWD (Sandström et al. 2007). In this study, the decay class was assessed for each log of CWD in the field; based on visual characteristics (Russell et al. 2015); into four classes using a modified CWD decay classification (Ifo et al. 2018) (Table 1).

Volume was converted to mass by multiplying the volume by 0.5 g/cm^3 as conversion factor: M=0.5 g/cm^3 (Reyes et al. 1992; Roshetko et al. 1999; Ekoungoulou et al. 2018). Assuming that carbon is stored in forest biomass and has a relationship, the amount of biomass is multiplied by 0.5 to get estimated carbon for each plot, because 50% biomass are assumed as stored in the forest (Pearson and Brown 2005; Chave et al. 2009; Uykun 2018).

Statistical analysis

All statistical analyses were done using R software and

Table 1. Decay classes of coarse woody debris (CWD)

Decay states	Characteristics
Class 1	More than 75% of wood still intact and a good part of the bark was still intact, twigs and leaves attached, the metal does not penetrate
Class 2	25-50 % of wood beginning to be soft and bark only partially convert; lacked of fine twigs and leaves
Class 3	75 % of the tree trunk has decayed, the bark is totally degraded
Class 4	More than 75 % of wood has decayed

Excel. The normality distribution and correlation were tested by using the Shapiro-Wilk normality test. If data were not normally distributed, then Wilcoxon/ Mann-Whitney test was used in order to compare the difference between medians. In contrast, when data were normally distributed, it was subjected to one-way anova, p-value <0.05 was considered as significant.

Results and Discussion

Diameter

There was a great disparity in diameter size of CWD among sites. An average of 24.7 cm (range 10-67 cm) was observed at the Mpo Impini site and 28.8 cm (range 10-89 cm) at the Impini site. Frequency distribution of diameter was analyzed and it showed a tendency that the number of logs decreases gradually when the diameter increased. It was slightly higher in diameter classes <50 cm.

The distribution of diameter and its distribution in decay states in both sites reveals that class 3; has high with percent of 29.56 %, followed by class 1; 28.26. Class 2 and class 4 have respectively 21.3 and 20.87%. Based on the compilation of data, we found in general that there was a significant difference in the median CWD diameter across decay classes (Kruskal-Wallis chi-squared=14.221, df= 3, p-value=0.002619). Using the Wilcoxon test, the test indicated a significant difference between class 2 and class 4 (p-value=0.0019).

Volume

CWD volume per hectare was estimated for each plot across the sites. The highest volume estimated was 294.17 m^3/ha at Mpo impini site and the lowest volume measured was 17.27 m^3/ha at the Impini site, with a general average of 117.94 m^3/ha. Estimates of volume means between Mpo Impini (mean=118.88 m^3/ha) is slightly higher than Impini (mean=116.33 m^3/ha) (Table 2). The dispersion of CWD volume in different classes varied among the sites. A one-way analysis of variance (ANOVA) was used to compare the total mean of CWD volume (m^3/ha) in each site. With an F-value of 0.011 and p- value of 0.919, the sites were statistically compared.

Mass and carbon stock

The estimation of the mass of deadwood across the two sites revealed low changeability of mass at landscape scale. The proportion of total CWD mass was, on average, 58.93 Mg ha^{-1}. The mean mass was 59.38 Mg ha^{-1}at the Mpo Impini site, while at the Impini site it was 58.16 Mg ha^{-1}. Examining carbon stocks by site; with the average of 29.48 Mg C ha^{-1}; the lowest carbon stock was obtained at the Impini site with 4.31 Mg C ha^{-1} while the largest stock was recorded at the Mpo Impini site with 73.5 Mg C ha^{-1}. The average mass and carbon stocks vary from one site to another. The statistical comparison of the means does not indicate any significant difference in CWD carbon stocks across study sites (Table 3).

Table 2. Volume and relative proportions by sites

	All plots (n=230) m^3/ ha	Mpo Impini (n=155) m^3/ha	Impini (n=75) m^3/ha
Mean	117.94	118.31	116.33
Minimum	17.27	25.51	17.27
Maximum	294.17	294.17	262.93
Standard error	4.59	5.92	7.51
CV (%)	59	63	56

Table 3. Estimates of mass and carbon stocks

	Mass (Mg/ha)			Carbon (Mg C/ha)		
	All plots	Mpo Impini	Impini	All plots	Mpo Impini	Impini
Mean	58.93	59.44	58.17	29.48	29.72	29.084
Minimum	8.64	13.68	8.64	4.32	6.84	4.32
Maximum	147.09	147.09	131.47	73.54	73.54	65.77
Standard error	2.29	2.96	3.75	2.94	1.48	1.87
CV (%)	59	62	56	59	62	56

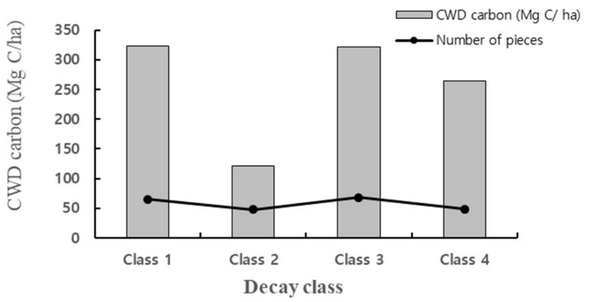

Fig. 2. Estimated carbon stocks of coarse woody debris (CWD) along decay class.

The allocation of CWD carbon stocks among the decay class of all the CWD samples on these two sites reveal that the most important classes were class 1 and class 3 with respectively mass 323.66 (31.36%) and 321.95 Mg C ha^{-1} (31.20%), followed by class 4 with 264.56 Mg C ha^{-1} (25.64%) and the last one was class 2 with 121.76 Mg C ha^{-1} (11.8%) (Fig. 2).

The estimated CWD carbon stocks obtained in our field were about double compared to others studies done in Congo Basin Forests. Ifo et al. (2017) analyzed data in the Likouala forest (Republic of Congo) and found an average of 9.45 t C/ha. In the northern Republic of the Congo, Ekoungoulou et al. (2018) reported that the mean of CWD stocks varied between 8.9 Mg/ha and 19.96 Mg/ha in Ipendja forest management unit. Moreover, Carlson (2013) investigated the CWD in the Gabon's forest and found that the carbon stocks were between 14 Mg C/ha to 30.1 Mg C/ha. In contrast, compare our CWD carbon stocks with those studies done in others tropical regions in America, we found that our results were comparable. Chao et al. (2008) found a necromass mean of 45.8 Mg/ha in the sand forests in the northwestern Amazonian landscape. Clark et al. (2002) found a CWD mass average of 46.3 Mg/ha in the tropical rain forest in Costa Rica. Therefore, we can conclude that CWD in this forest is an important component in carbon sequestration and should be taken into consideration for quantification of carbon stocks not only in Bombo-Lumene Reserve, but in all forest ecosystems in the Democratic Republic of Congo.

Acknowledgements

We are grateful to General Direction of "Institut Congolais pour la Conservation de la Nature" to allow us to conduct our research in this protected Area and also to all Bombo-Lumene Domain and Reserve Staff. We thank Bokoma, Mbo, Christian and many others for their technical assistance during field measurements.

References

Assefa G, Mengistu T, Getu Z, Zewdie S. 2013. Training Manual on: Forest Carbon Pools and Carbon Stock Assessment in the Context of SFM and REDD+. Hawassa University Wondo Genet College of Forestry and Natural Resources, Wondo Genet.

Baker TR, Honorio Coronado EN, Phillips OL, Martin J, van der Heijden GM, Garcia M, Silva Espejo J. 2007. Low stocks of coarse woody debris in a Southwest Amazonian Forest. Oecologia 152: 494-504.

Böhl J, Brändli UB. 2007. Deadwood volume assessment in the third Swiss National Forest Inventory: methods and first results. Eur J For Res 126: 449-457.

Carlson B. 2013. Gabon's Overlooked Carbon: A tropical forest study of coarse woody debris. MS thesis. Duke University, North Carolina, USA.

Chao KJ, Phillips OL, Baker TR. 2008. Wood density and stocks of coarse woody debris in a northwestern Amazonian landscape. Can J For Res 38: 795-805.

Chave J, Coomes D, Jansen S, Lewis SL, Swenson NG, Zanne AE. 2009. Towards a worldwide wood economics spectrum. Ecol Lett 12: 351-366.

Clark DB, Clark DA, Brown S, Oberbauer SF, Veldkamp E. 2002. Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. For Ecol Manag 164: 237-248.

de Madron LD, Bauwens S, Giraud A, Hubert D, Billand A. 2011. Estimation de l'impact de différents modes d'exploitation forestière sur les stocks de carbone en Afrique centrale. Bois For Trop 308: 75-86.

Dey A, Islam M, Masum KM. 2014. Above ground carbon stock through palm tree in the homegarden of Sylhet city in Bangladesh. J For Environ Sci 30: 293-300.

Ekoungoulou R, Niu S, Folega F, Nzala D, Liu X. 2018. Carbon stocks of coarse woody debris in Central African Tropical Forests. Sustain Environ 3: 142-160.

Fravolini G, Egli M, Derungs C, Cherubini P, Ascher-Jenull J, Gómez-Brandón M, Bardelli T, Tognetti R, Lombardi F, Marchetti M. 2016. Soil attributes and microclimate are important drivers of initial deadwood decay in sub-alpine Norway spruce forests. Sci Total Environ 569-570: 1064-1076.

Fukasawa Y. 2012. Effects of wood decomposer fungi on tree seedling establishment on coarse woody debris. For Ecol Manag 266: 232-238.

Habiyaremye FM, Lukebakio N, Ngaliema M. 2011. Habitats de la Réserve et Domaine de chasse de Bombo-Lumene (R.D. Congo): Lexique Kiteke des plantes observées dans ces milieux. Institut royal des Sciences naturelles de Belgique, Bruxelles.

Hagan JM, Grove SL. 1999. Coarse woody debris: humans and nature competing for trees. J For 97: 6-11.

Harmon ME, Woodall CW, Fasth B, Sexton J, Yatkov M. 2011. Differences Between Standing and Downed Dead Tree Wood Density Reduction Factors: A Comparison Across Decay Classes and Tree Species. United States Department of Agriculture, Washington. Research Paper NRS-15.

Herrmann S, Kahl T, Bauhus J. 2015. Decomposition dynamics of coarse woody debris of three important central European tree species. For Ecosyst 2: 27.

Ifo AS, Koubouana F, Jourdain C, Nganga D. 2015. Stock and flow of carbon in plant woody debris in two different types of natural forests in Bateke Plateau, Central Africa. Open J For 5: 38-47.

Ifo SA, Binsangou S, Mbemba M. 2018. Décomposition des gros débris ligneux dans les forêts tropicales humides du bassin du Congo. Int J Biol Chem Sci 12: 837-849.

Ifo SA, Mbemba M, Koubouana F, Binsangou S. 2017. Stock de carbone dans les gros débris ligneux végétaux: cas des forêts tropicales pluvieuses de la Likouala, République Du Congo. Eur Sci J 13: 384-399.

Inogwabini BI, Amube J, Bagurubumwe N, Bakanseka JM, Bakanza A, Basinyire P, Bikanza M, Bikumbu H, Bongwele E, Chibembe A, Iyomi BI, Karamba J, Kasongo N, Kayeye H, Lola P, Madidi J, Mafuta N, Mangoni G, Masasu F, Mayifilua J, Mbende M, Mbenzo BA, Ngomba MN, Nlemvo B, Ntumba B, Ohole AN, Pasi MS, Yata F, Zanga NL. 2006. Formation sygiap- troisieme phase: rapport technique de la session de Bombo Lumene. Institut Congolais pour la Conservation de la Nature, Kinshasa.

Kalambay BM, Rudant JP, Lumbuenamo R, Beland M, Riera B. 2016. Spatial dynamic of the hunting area and Bombo Lumene reserve between 2000 and 2015 by optical satellite imagery. Int J Innov Appl Stud 18: 559-568.

Kangas A, Maltamo M. 2006. Forest Inventory: Methodology and Applications. Springer, Dordrecht.

Kayumba M, Lubini C, Kidikwadi E, Habari JP. 2015. Floristic study of the mature formation of Bombo-Lumene Domain and Reserve (Kinshasa / RD Congo). Int J Innov Appl Stud 11: 716-727.

Keller M, Palace M, Asner GP, Pereira R Jr, Silva JNM. 2004. Coarse woody debris in undisturbed and logged forests in the eastern Brazilian Amazon. Glob Chang Biol 10: 784-795.

Kim S, Kwon B, Son Y, Yi MJ. 2018. Carbon storage in an age-sequence of temperate Quercus mongolica stands in central Korea. J For Environ Sci 34: 472-480.

Kraigher H, Jurc D, Kalan P, Kutnar L, Levanič T, Rupel M, Smolej I. 2002. Beech coarse woody debris characteristics in two virgin forest reserves in Southern Slovenia. Zbornik Gozdarstva Lesarstva 69: 91-134.

Maraseni TN, Mitchell C. 2016. An assessment of carbon sequestration potential of riparian zone of Condamine Catchment, Queensland, Australia. Land Use Policy 54: 139-146.

Merganičová K, Merganič J. 2010. Coarse woody debris carbon stocks in natural spruce forests of Babia hora. J For Sci 56: 397-405.

Milau F, Kifukieto C, Kachaka C, Aloni J, Francis F. 2016. Contribution à l'étude de la faune associée à la décomposition du bois (Isoptera et Haplotaxida) à Bombo-Lumene au plateau des Batékés (RDC). Entomol Faun 69: 37-44.

Milau F. 2016. Etude de la diversité des communautés lombriciennes dans la Réserve et Domaine de Chasse de Bombo-lumene, plateau des Batékés. Dissertation. Université de Kinshasa, Kinshasa, Congo. (in French)

Monfils MJ, Kost MA, Weber CR, Donovan ML, Brown PW. 2009. Comparisons of coarse woody debris in northern Michigan forests by sampling method and stand type. Michigan Natural Features Inventory, Michigan. Report Number 2009-12.

Moyene AB. 2008. Valorisation des produits forestiers non ligneux des plateaux de Batéké en périphérie de Kinshasa (RD Congo). PhD thesis. Université libre de Bruxelles, Bruxelles, Belgium. (in French)

Muller RN, Liu Y. 1991. Coarse woody debris in an old-growth deciduous forest on the Cumberland Plateau, southeastern Kentucky. Can J For Res 21: 1567-1572.

Netto SP, Pelissari AL, Bribeiro A, Machado SA, Nascimento RGM. 2018. Sampling system for estimating woody debris in an urban mixed tropical forest. An Acad Bras Cienc 90: 3769-3780.

Pearson T, Brown S. 2005. Guide de mesure et de suivi du carbone dans les forêts et prairies herbeuses. Arlington, Winrock International.

Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, Wagner F. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Institue for Global Environmental Strategies, Kanagawa.

Reyes G, Brown S, Chapman J, Lugo AE. 1992. Wood Densities of Tropical Tree Species. New Orleans, U.S. Dept of Agriculture, Forest Service. SO-88. pp 15.

Roshetko JM, Delaney M, Hairiah DK, Purnomosidhi P. 1999. Carbon stocks of homegarden systems in Lampung, Indonesia. In: Toward sustainable agriculture in humid tropics facing 21st century; Bandar Lampung, Indonesia; Sep 27-28, 1999.

Sandström F, Petersson H, Kruys N, Ståhla G. 2007. Biomass conversion factors (density and carbon concentration) by decay classes for dead wood of Pinus sylvestris, Picea abies and Betula

spp. in boreal forests of Sweden. For Ecol Manag 243: 19-27.
Sato T. 2010. Stocks of coarse woody debris in old-growth lucidophyllous forests in southwestern Japan. J For Res 15: 404-410.
Silva LFSG, de Castilho CV, de Oliveira Cavalcante C, Pimentel TP, Fearnside PM, Barbosa RI. 2016. Production and stock of coarse woody debris across a hydro-edaphic gradient of oligotrophic forests in the northern Brazilian Amazon. For Ecol Manag 364: 1-9.
Simon E. 2006. The IPCC 2006 Guidelines and Their Evolution from the Revised 1996 Guidelines. IPCC, Geneva.
Stares MG, Collins L, Law B, French K. 2018. Long-Term effect of prescribed burning regimes and logging on coarse woody debris in South-Eastern Australia. Forests 9: 242.
Taylor SW. 1997. Une méthode d'évaluation sur le terrain des débris ligneux grossiers. Natural Resources Canada, Canadian Forest Service, Ottawa. 6 pp.
Teissier du Cros R, Lopez S. 2009. Preliminary study on the assessment of deadwood volume by the French national forest inventory. Ann For Sci 66: 302.
UICN/PACO. 2010. Parcs et réserves de la République Démocratique du Congo: évaluation de l'efficacité de gestion des aires protégées. UICN/PACO, Ouagadougou.
Uykun C. 2018. Above-ground biomass and carbon estimations and recommendations for forests in Turkey. MS thesis. Michigan Technological University, Michigan, USA.
Van Wagner CE. 1968. The line intersect method in forest fuel sampling. For Sci 14: 20-26.
Vermeulen C, Lanata F. 2006. Le domaine de chasse de Bombo-Lumene: un espace naturel en péril aux frontières de Kinshasa. Parcs Réserv 61: 4-8.
Yan E, Wang X, Huang J. 2006. Concept and classification of coarse woody debris in forest ecosystems. Front Biol China 1: 76-84.
Yuan J, Hou L, Wei X, Shang Z, Cheng F, Zhang S. 2017. Decay and nutrient dynamics of coarse woody debris in the Qinling Mountains, China. PLoS One 12: e0175203.