Forest Ecology and Management 295 (2013) 51–58

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Deadwood basic density values for national-level carbon stock estimates in Italy

L. Di Cosmo [a,*], P. Gasparini [a], A. Paletto [a], M. Nocetti [b]

[a] *Consiglio per la Ricerca e la sperimentazione in Agricoltura, Unità di Ricerca per il Monitoraggio e la Pianificazione Forestale (Agricultural Research Council – Forest Monitoring and Management Research Unit), Piazza Nicolini 6, 38123 Trento, Italy*

[b] *CNR–IVALSA, Via Madonna del Piano 10, I-50019 Sesto Fiorentino, Italy*

A R T I C L E   I N F O

Article history:
Received 21 June 2012
Received in revised form 8 January 2013
Accepted 10 January 2013
Available online 19 February 2013

Keywords:
Deadwood
Necromass
Decay class
Basic density
National forest inventory
Italy

A B S T R A C T

Deadwood biomass is one of the five terrestrial carbon pools that are relevant for the estimation of carbon stocks and carbon stock changes under the UNFCCC and the Kyoto Protocol (IPCC Guidelines for National Greenhouse Gas Inventories). Statistics on this important ecosystem component are generally provided by national forest inventories: in the last few decades, national forest inventories in Europe have gradually included deadwood among the traditionally investigated components. However, deadwood is generally surveyed in terms of volume, which is then converted to biomass using basic density values. These are rarely specifically derived for the population under estimation; more often, values available from the literature and based on the findings of local studies are used instead. Based on a survey conducted by the Italian national forest inventory in 2008 and 2009 that specifically intended to more deeply investigate the carbon storage of forests, samples of deadwood were collected all over the country from the plots of the national forest inventory network and used to derive basic density values. This paper presents the basic densities obtained for groups of species (conifers, broadleaves), deadwood components (coarse woody debris, standing dead trees, stumps) and decay classes (using a five-class system). Fine woody debris was also surveyed, but in terms of weight and not volume. For such material, the ratio of dry weight to fresh weight for conversion to biomass is presented. In addition, the main aspects of the field protocol are discussed. Lastly, the use of less accurate, generalised basic density values is tested to evaluate its effects on deadwood biomass estimates.

1. Introduction

Deadwood biomass (or necromass) plays a key role in the functioning and productivity of forest ecosystems (Harmon et al., 1986; Humphrey et al., 2004). Standing and fallen non-living wood pieces are special habitats for many species (mammals, birds, amphibians, insects, polypores and other saproxylic fungi, moss and lichen communities) (Nordén et al., 2004) and contribute to the structural and biological diversity of ecosystems, as many organisms (both directly and indirectly dependent) are adapted to utilise them as a resource (Aakala, 2010).

Deadwood is also an important factor in nutrient cycles (N, P, Ca and Mg) (Laiho and Prescott, 1999; Holub et al., 2001) and a fundamental element in ecological, geomorphological and soil hydrological processes (Bragg and Kershner, 1999). Furthermore, non-living woody biomass is an important forest carbon pool (Ravindranath and Ostwald, 2008); it slows the release of carbon dioxide due to decomposition and in this way, it has the potential to moderate global warming by decreasing the build-up of carbon dioxide (Keller et al., 2004). The IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2003) assume that ''changes in deadwood carbon stocks are not significant, and can be assumed zero, i.e. that inputs balance losses'' but also state that ''dead organic matter should be considered in future work on inventory methods because the quantity of carbon in dead organic matter is a significant reservoir in many of the world's forests''. Accordingly, the estimation of deadwood carbon stock changes is explicitly required for reporting under Tiers 2 or 3.

Deadwood can account for a substantial fraction of the carbon stored in forests. However, until recently, necromass estimates over large areas such as regions or countries were still rare (Delaney et al., 1998; Chojnacky and Heath, 2002; Heath and Chojnacky, 2001; Woodall et al., 2008). Currently, estimates of deadwood biomass are generally available from National Forest Inventories (NFIs), which have included deadwood among the attributes surveyed in response to the increased awareness of its ecological importance. To closely harmonise country-based estimates, the publication of deadwood inventory procedures and protocols has been recommended (Woodall et al., 2006). In Europe, almost all NFIs estimate deadwood volume, and major efforts are being made to harmonise their estimates, as comparisons are still difficult because of inconsistencies due to the use of slightly different size thresholds such as the minimum diameter or length of the dead-

* Corresponding author. Tel.: +39 0461 381149; fax: +39 0461 381131.
E-mail address: lucio.dicosmo@entecra.it (L. Di Cosmo).

0378-1127/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2013.01.010

wood pieces surveyed (see examples in Country reports, Tomppo et al., 2010). In most European countries, deadwood volume ranges, as a percentage of growing stock, from 3.3% (Belgium) to 14.4% (Slovak Rep.), but more frequently it accounts for 5–7% (Sweden, Finland, Luxembourg, Italy, Estonia), with additional cases over 7% (Ireland 8.1% and Switzerland 9.5%) (see country reports in Tomppo et al. (2010)).

The assessment of the deadwood contribution to carbon storage requires the conversion of deadwood volumes to biomass using basic density values. However, in general, NFIs do not provide basic densities, and values available from the literature are used instead. The use of these values has been regarded as a good practical solution, but only to provide a first approximation, as it increases the potential for errors (Harmon and Sexton, 1996). The lack of appropriate values often results in the use of the few values available for estimating deadwood biomass over large areas and a great variety of species even though the available values were obtained by local studies and/or for a limited number of species. For example, Woodall et al. (2008) applied conversion factors from Waddell (2002), that were obtained by modelling the gravity reduction of hardwoods using data (from Harmon and Sexton (1996)) from a rather limited number of species.

The three-phase second Italian NFI (2003–2007) initially provided statistics on deadwood volume by forest category and administrative region. Quantitative measurements for deadwood volume estimates were conducted during the third inventory phase. An additional survey specifically addressing the assessment of carbon stored in deadwood biomass, understory vegetation, litter and soil, was conducted in the growing seasons of 2008 and 2009 in a subsample of the inventory sampling units (Gasparini et al., 2010a; Gasparini, 2011). During this supplementary assessment, samples for deriving factors to convert deadwood volume to biomass were collected. As a result of these two surveys, the carbon stored in deadwood biomass was estimated to be 24,855,508 MgC (2.8 MgC ha^{-1}), corresponding to the 5.4% of the carbon stored in the aboveground live biomass and to the 2.0% of the total carbon stored in the Italian forests (above-ground live biomass, deadwood, litter and soil), which amounts to 1,225,385,636 MgC (139.9 MgC ha^{-1}) (www.infc.it).

This article presents, for the first time, the basic density values resulting from the extensive sampling of dead woody materials conducted by the Italian national forest inventory to provide accurate national-level estimates of deadwood biomass. Basic density values are provided for three deadwood components – coarse woody debris, standing dead trees and stumps – by decay class and for two groups of species, conifers and broadleaves. Differences among mean basic densities were analysed to test for statistical significance. For the fine woody debris component of deadwood, the dry to fresh weight ratio is provided instead of the basic density value. The main aspects of the measurement protocol are discussed to provide practical information that will be useful for future applications. Finally, a simulation was performed to test the effects of using artificially generalised basic densities on deadwood biomass estimates.

2. Materials and methods

2.1. Definitions of deadwood components

Four different deadwood components were surveyed by the Italian NFI: Coarse Woody Debris (CWD), Standing Dead Trees (SDTs), Stumps and Fine Woody Debris (FWD). CWD includes fallen dead trees and branches lying on the ground with a minimum end diameter (diameter of the narrower end section of the deadwood piece) of 9.5 cm (Fig. 1); SDTs include all dead trees still standing

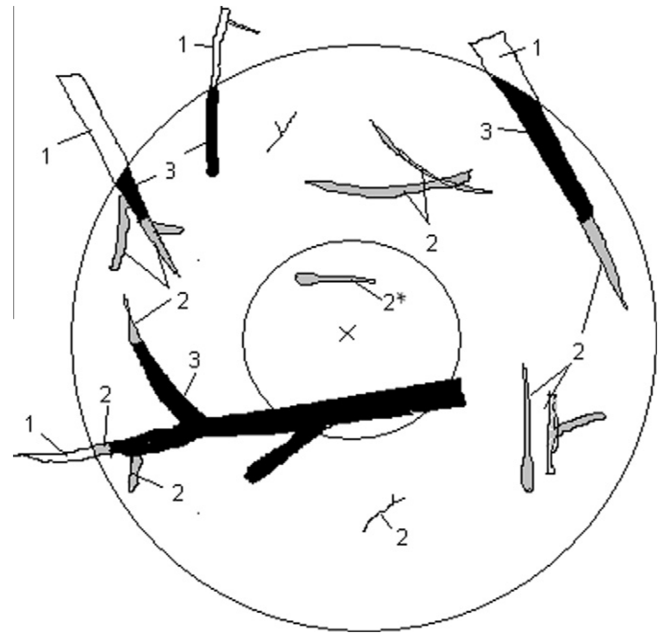

Fig. 1. Selection of CWD during the third inventory phase. The measured portions are those labelled with the number 3. Portions labelled with the numbers 1 and 2 were not measured because they lay outside the 13 m radius plot or have a maximum end diameter <9.5 cm. Note that in the supplementary survey the piece labelled with 2* would be measured as FWD.

with a diameter at breast height (or DBH) ⩾4.5 cm; Stumps include the portions of trees remaining after cutting or less frequently the stems truncated from natural hazards not reaching a height of 1.30 m and with a diameter at least 9.5 cm at the cut section (or breaking section). Finally, FWD includes all deadwood pieces lying on the ground with end diameters between 2.5 cm and 9.4 cm. Dead and still-standing trees with a DBH between 2.5 cm and 4.4 cm were downed and considered as part of the FWD. The survey protocol does not provide for any length requirement (e.g. minimum length threshold). Pieces with end diameters narrower than 2.5 cm were not considered to be part of the deadwood; the Italian NFI considers their contribution to carbon storage but considers and samples them as part of the litter. Except for FWD, all of the above components were classified according to their species group (conifers or broadleaves) and class of decay. A five class system was adopted from Morelli et al. (2007) and Paletto and Tosi (2010), with classes defined as shown in Table 1. Originally, these classes were obtained by modifying those reported in Naesset (1999), considering some important operational aspects underlined by Humphrey et al. (2004) to base classification exclusively on visual assessment.

2.2. Survey protocol and deadwood volume estimation

Quantitative measurements for deadwood volume estimates were conducted in the third inventory phase within two concentric, circular plots centred on 6685 NFI sampling points (INFC, 2006; Gasparini et al., 2010b).

CWD was measured within a 13 m radius plot; in the case of deadwood pieces crossing the plot boundary, only the inside portion was considered (Fig. 1). For each piece, two perpendicular diameters were measured at the two end sections and the length was measured. Long pieces were ideally divided into fragments no longer than 2 m, or less if irregularly shaped, to approximate them as closely as possible to a regular geometric solid. The volume of each fragment was calculated by assimilating it into a