Environmental Sciences Proceedings

MDPI

Proceedings

Characterisation of Woody Necromass in Beech Forests with Different Anthropic Accessibility: the Case of La Rioja (Spain) †

Ilaria Collepardi [1,*], Emanuele Ziaco [2], César Pérez Cruzado [3] and Angela Lo Monaco [1]

1 Department of Agriculture and Forest Sciences (DAFNE), University of Tuscia, Via S. Camillo de Lellis, 01100, Viterbo, Italy; ilaria.collepardi@hotmail.it; lomonaco@unitus.it
2 Department of Natural Resources & Environmental Science, University of Nevada, 1664 N. Virginia Street, Reno, NV 89557, USA; emanueleziaco@hotmail.com
3 Higher Polytechnic School of Engineering, University of Santiago de Compostela, Benigno Ledo s/n E-27002, Lugo, Spain; cesar.cruzado@usc.es
* Correspondence: ilaria.collepardi@hotmail.it; Tel: +39-3271461456

† Presented at the 1st International Electronic Conference on Forests, 15–30 November 2020; Available online: https://sciforum.net/conference/IECF2020

Published: date

Abstract: In this study a comprehensive analysis of deadwood was conducted in four macro-areas located in two beech forests of public utility in Enciso (La Rioja, Spain). Dendrometric data, as well as qualitative and quantitative characteristics of deadwood were collected and analyzed with respect to the degree of accessibility to the forest to determine the effect of different levels of forest accessibility on deadwood volume and carbon stocks. All decomposition classes were present except the first, highlighting the development of natural degradation dynamics. Deadwood stored 6.9 t/ha of C in the easy accessibility class, 5.7 t/ha of C in the medium accessibility class and 2.2 t/ha of C in the difficult accessibility class. The average volume of deadwood and carbon stored calculated in this study were higher than the values reported in the Spanish and Italian national forest inventories, including the one developed for the Riojan beech forests. Deadwood volume was on average 22.5 m^3/ha, showing an unequal distribution, with the lowest values found far from the access roads, despite forest accessibility is generally considered a factor that facilitates the human collection of deadwood. The distribution patterns of deadwood in beech forests of La Rioja, apparently counterintuitive, were due to a combination of different factors, including slope, cattle grazing, and weather conditions which might have favored downward movement of the deadwood.

Keywords: deadwood; beech forests; decay classes; accessibility classes; carbon

1. Introduction

In beech forests, where the frequency of fires is very low, wood decomposes within the forest and this implies the existence of an entire trophic network that has evolved in conditions of abundance of this resource [1].

The terms "woody necromass" and "deadwood" define dead woody mass, including standing dead trees (snags), deadwood on the ground (logs) and dead stumps. In October 2002, during the Expert Level Meeting of the Ministerial Conference on the Protection of Forests in Europe, deadwood volume was included among the pan-European quantitative indicators of Sustainable Forest Management, in support of Criterion 4, aimed at the maintenance, conservation and appropriate improvement of biological diversity in forest ecosystems. Deadwood was distinguished into *Standing Dead Tree - SDT* or *snags* - and *Lying deadwood* or *logs*, the latter defining deadwood on the ground, which can be further distinguished in *Coarse Woody Debris* or *CWD*, i.e. coarse woody detritus with a diameter of the smallest section equal to or greater than 10 cm, and *Fine Woody Debris* or *FWD*, i.e. fine woody detritus with a diameter between 10 and 2.5 cm [2-4]. Woody debris with a diameter of less than 2.5 cm is considered part of the litter [4-5]. CWD provide many micro-habitats for several species of micro- and macro-fauna, and the diametric variability of CWD can substantially increase forest biodiversity. For instance, Stokland et al. [6] found that some species prefer small diameters <20 cm, other ones colonize only dry woods with diameters greater than 20 cm or even 40 cm, while only ~20% of the species examined were found to be generalist [6]. However, these diametric thresholds cannot be generalized since the size and abundance of deadwood are highly variable and depend on forest type, successional phase, climate, and forest management practices [7-10]. Furthermore, the potential benefits for biodiversity depend on the level of decay of deadwood, either snags, logs or stumps, and on the presence of all decay classes in the forest (from recently dead stems to highly decomposed debris) [11].

The objective of this research was to quantify and qualify deadwood in two beech forests of the Spanish autonomous community La Rioja, in order to determine the effect of different levels of forest accessibility on deadwood. Moreover, using values established by the Intergovernmental Panel on Climate Change (IPCC) in 2006 [12], we contributed to define estimates of the amount of carbon (C) stored both in living trees and in the deadwood within beech forests of La Rioja.

2. Materials and Methods

2.1. Study Area

La Rioja is the second smallest Spanish autonomous community (5,045 km^2), and it has the lowest number of inhabitants (315,675, for a density of 62.57 inhabitants/km^2) [13]. La Rioja has a wide variety of landscapes, flora and fauna, due to the different geographical characteristics of its areas: it is possible to distinguish a valley area in the north, called "Valle del Ebro", and a mountainous area in the south, called "Sistema Ibérico". The proximity with the Atlantic Ocean and the Mediterranean Sea greatly influences climatic variability in a region characterized by complex topography. Hence, climatic conditions in La Rioja are remarkably heterogeneous, but in general characterized by cold and humid winter season, with frequent snowfalls both on the mountain ranges and in some valleys, while the summer season is dry and hot, with minimal rainfall. Spring and autumn are characterized by mild temperatures and abundant rains, especially in spring. Yearly temperature generally varies from -2 °C (January) to 26 °C (August) and rarely drops below -3 °C or rises above 35 °C. The average annual rainfall is 400 mm. La Rioja has a total extension of over half a million hectares, of which almost 62% is devoted to forest use, higher (7%) than the national average. More than half (66%) of La Rioja's forest area is publicly owned, and the remaining 34% is privately owned [14].

The study area is about 10 km away from the historic center of Enciso, a municipality of La Rioja with a population of about 170 inhabitants. This study was conducted in two pure beech forests, despite in the surrounding areas beech stands are often located near or intermixed with reforested stands of *Pinus sylvestris*. Stands located in areas characterized by difficult accessibility are generally left to natural evolution, given their relevance from a conservation, soil protection, and aesthetical point of view. On the other hand, more accessible stands undergo phytosanitary thinning or cuts, following the approval of a Project or Technical Plan for the Management of Forest Resources of Public Utility Forests, as established by Law 2/1995, concerning Protection and development of the forest heritage of La Rioja [14]. The studied beech forests, located on slopes of 10-20%, are even aged high forests, with small coppice areas. They are not subjected to any management plan, but there may have been legal concessions in past years.

2.2. Data Collection

The field surveys were carried out for gathering 1) dendrometric information of the stand, 2) quantitative and 3) qualitative description of deadwood. Th**e** **s**urveys were conducted in four macro-areas of study (MAS1, MAS2, MAS3, MAS4) located within beech forests served by forest roads. In each MAS three circular plots with a radius of 20 m and a surface of 1256 m² each were established, for a total of twelve sampling plots. The presence of a quantitative gradient of deadwood from the access roads to the inner forest was investigated by placing the three plots in each MAS at increasing distance from the access road to define three accessibility classes: the easy accessibility class from 20 to 60 m (E); the medium accessibility class from 60 to 100 m (M); and the difficult accessibility class from 100 to 140 m (D). Being located on slopes, increasing distance from the road always corresponded to an increase in altitude: as a result, MAS1 ranged between 1400 and 1430 m a.s.l., MAS2 between 1340 and 1365 m a.s.l., MAS3 between 1295 and 1310 m a.s.l., and MAS4 between 1490 and 1515 m a.s.l. For each plot, elevation, slope, aspect, and coordinates were recorded. Once the center of the plot was identified, for each living tree, diameter at breast height (DBH) was recorded using a caliper to the nearest millimeter; for each snag, height using a Vertex hypsometer with metric precision, decay class, and DBH and diameter at half height (for snags with total height equal to or less than 4 meters) were recorded; for each dead stump, diameter, height and decay class were recorded. Furthermore, the height of at least 8 live trees/plot were measured, generally at least two per diameter class. To obtain the quantitative and qualitative information of the logs, two linear transects 50 m long and 1 m wide were performed in each plot, perpendicular to each other and with the center falling in the same center of the plot. The parameters of the logs with a diameter ≥2.5 cm, snags, and dead stumps were measured along the transect. The degree of decay of deadwood was defined using the visual classification system of Hunter [15] and Morelli et al. [16]. According to the classification system, each snag, log and dead stump was assigned to a specific decay class.

2.3 Data Analysis

Tree density (trees/ha), basal area (m²/ha), average diameter (cm), and average height (m) were calculated for each MAS. The woody volume per hectare (m³/ha) of each sampling area was calculated using double-entry volume tables [17]. In order to convert living trees and deadwood volumes in carbon stocks, the carbon concentration and the basal density typical of the species are needed. Since these values were not available for the Riojan beech, reference values for carbon concentration were obtained from the Intergovernmental Panel on Climate Change [12] (49% of the dry mass of living trees). The basic density of deadwood varies according to the decay class. In this study, values obtained experimentally for central Italian beech [18] were used, according to which the five decay classes had a basic density of 0.61 t/m³, 0.51 t/m³, 0.45 t/m³, 0.42 t/m³, and 0.24 t/m³ respectively. Differences in volumes found in each plot and decay class were investigated for categories of deadwood (snags, logs and dead stumps) and forest accessibility class using Tukey's test and ANOVA after homogeneity of variances between sampling plots had been assessed using the Levene's test.

3. Results

3.1 Results of the Dendrometric Analysis

The results of the dendrometric analysis are shown in Table 1. For each MAS, density, basal area, average diameter, average height and average volume were reported. The p-value shows the results of the ANOVA.

Table 1. Results of the dendrometric analysis for each MAS.

Parameter	MAS1	MAS2	MAS3	MAS4	p-value
Density (trees/ha)	916	406	451	496	<0,05
Basal area (m²/ha)	33.8	34.7	35.2	39.6	<0,05
Average diameter (cm)	21.7	33	31.5	31.8	<0,05
Average height (m)	16.7	19.8	19.5	19.6	<0,05
Average volume (m³/ha)	402	506	504	566	<0,05

3.2. Results of the Qualitative and Quantitative Analysis of the Deadwood

The quantitative analysis of volumes in snags, dead stumps and logs, by MAS and accessibility class showed that in most cases the D plots had on average the lowest deadwood volume (9.9 m³/ha) (Figure 1, Figure 2). The largest deadwood volume was found in the E plots (31.6 m³/ha), followed by the M plots (25.7 m³/ha) (Figure 2). Hence, the average volumes of snags, logs, and dead stumps decreased with decreasing accessibility (Figure 1).

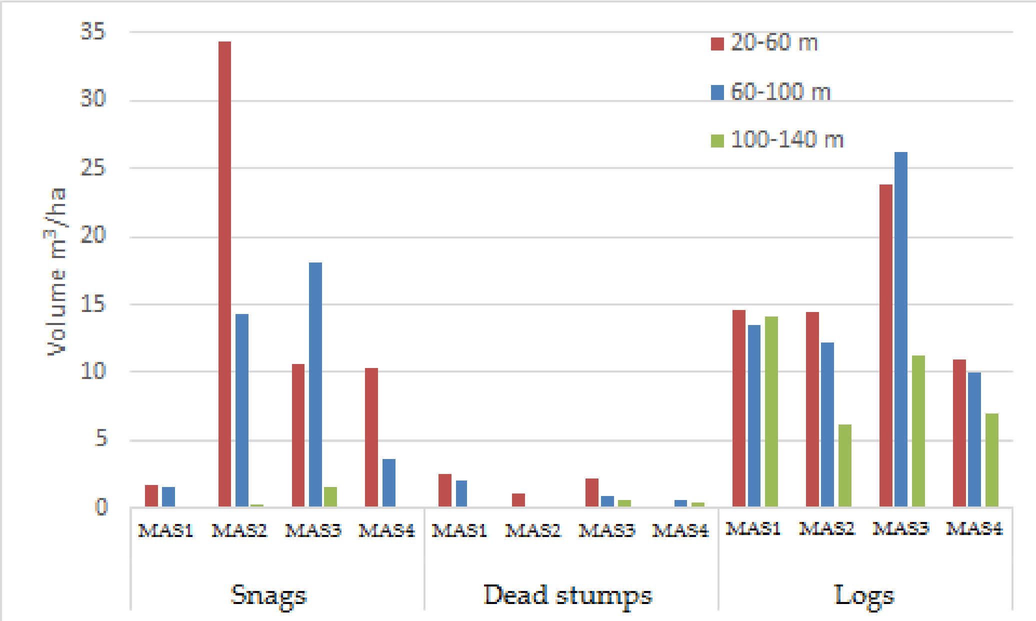

Figure 1. Volumes of snags, dead stumps and logs divided by MAS and accessibility classes.

Deadwood volume decreased from the easy accessibility class to the forest to the difficult one (Figure 2). In relative terms, deadwood represented 5.9% of the total volume (biomass + necromass) in the easy accessibility class, 5.1% in the medium accessibility class, and only 2% in the difficult accessibility class.

The Tukey test was applied to check if there were statistically significant differences within the same deadwood category as the accessibility class changed. The same letters within each category indicated no statistical difference based on the accessibility class (Figure 2, Figure 3). Deadwood in general and snags denoted that as the accessibility class increased, the average volumes decreased in a statistically significant way. The average volumes of dead stumps and logs decreased more gradually as no significant difference was detected in the E and M plots (Figure 2). It is interesting to note that the difference in deadwood total volume were driven by the snag volume in E and M as dead stump and log volume showed no statistical difference.

Deadwood in general had an average decay value of 3 in each accessibility class, hence no statistical differences were detect by the Tukey test (Figure 3). Snags had an average decay value of 3 in the E and D plots, of 2 in the M plot, in fact the Tukey test revealed this difference. Dead stumps had an average decay value of 4 in the E and M plots, statistically different from those in the D plot. Logs had an average decay value of 3 in the E and M plots, of 2 in the D plot, statistically different from those in the D plot. The Tukey test detected the statistical diference between the E and M plots, and the D plot (Figure 3). Hence, all the decay classes were present, except the first (Figure 3).

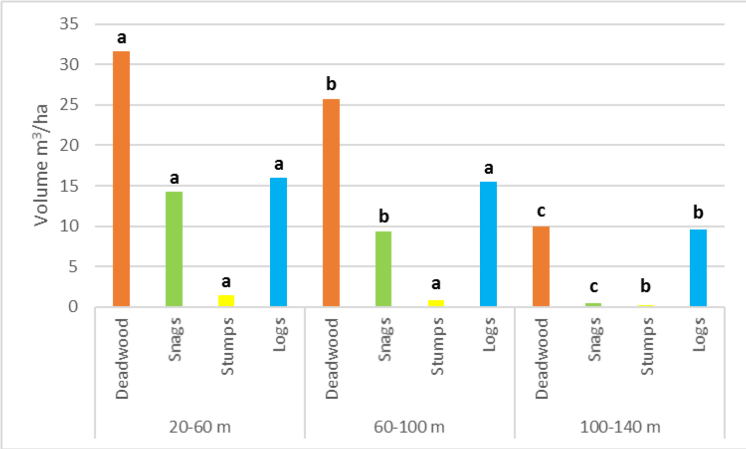

Figure 2. Volumes of deadwood categories for each accessibility class. Different letters indicate significant statistical difference by Tukey test in total deadwood and each deadwood category.

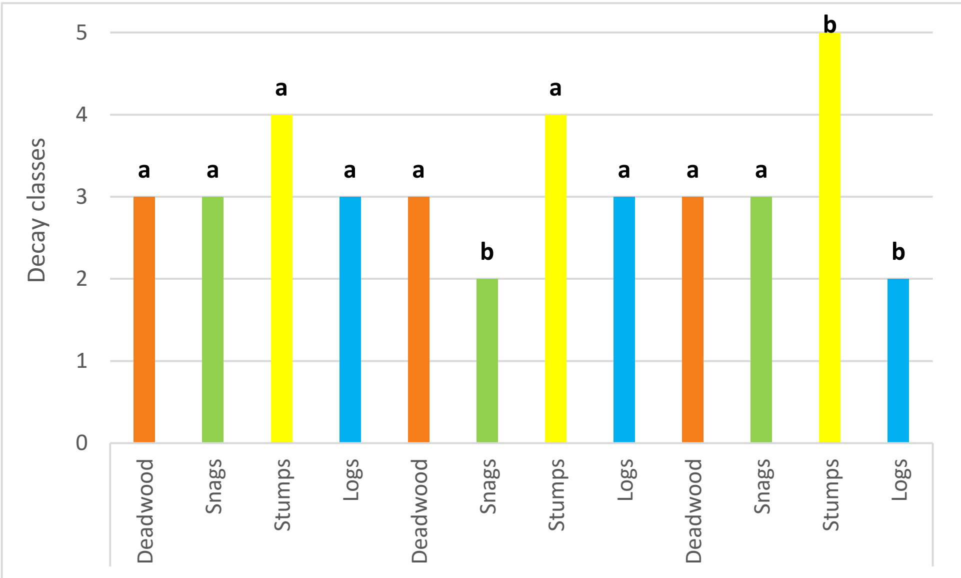

Figure 3. Decay classes of the categories of deadwood for each accessibility class. Different letters indicate significant statistical difference by Tukey test in total deadwood and each deadwood category.

3.3. Carbon Storage

Live trees had an average biomass of 289.2 t/ha in the easy accessibility classes, 273.8 t/ha in the medium accessibility classes, 282.3 t/ha in the difficult accessibility classes, and stored respectively 141.7 t /ha, 134.2 t/ha and 138.3 t/ha of C.

Total deadwood was on average 14.2 t/ha in the easy accessibility class, 11.6 t/ha in the medium accessibility class, 4.5 t/ha in the difficult accessibility class, stocking respectively 6.9 t/ha, 5.7 t/ha and 2.2 t/ha of C. Specifically, snags showed an average mass of 6.4 t/ha in the easy accessibility class, 4.8 t/ha in the medium accessibility class, 0.2 t/ha in the difficult accessibility class, stocking respectively 3.2 t/ha, 2.4 t/ha and 0.1 t/ha of C. Dead stumps had an average mass of 0.6 t/ha in the easy accessibility class, 0.4 t/ha in the medium accessibility class, 0.1 t/ha in the difficult accessibility class, stocking respectively 0.3 t/ha, 0.2 t/ha and 0.032 t/ha of C. The logs had an average mass of 7.2 t/ha in the easy accessibility class, 6.9 t/ha in the medium accessibility class, 4.9 t/ha in the difficult accessibility class, stocking respectively 3.5 t/ha, 3.4 t/ha and 2.4 t/ha of C.

4. Discussions

The volume of the deadwood decreased with the lower accessibility. This trend is opposite to the knowledge in literature, in fact the accessibility to the forest is considered a factor that facilitates the collection of deadwood by man, and generally, a decrease in the amount of deadwood is expected approaching the access road [19]. Other factors may affect accessibility as ground slope and its direction relative to the road. The size and decay class of deadwood can also influence the propensity to collect. The human use of deadwood as fuel is normally more related to the fallen tree than to snags or dead stumps as well as to the lower decay class [19].

The volume of deadwood found was compared with the data of the National Forest Inventory of La Rioja [20]. The inventory shows in the beech forests of La Rioja 3.74 m^3/ha standing dead trees with DBH>7.5 cm, 0.49 m^3/ha of standing dead trees with DBH<7.5 cm, 3.86 m^3/ha of logs with DBH>7.5 cm, 0.39 m^3/ha of logs with DBH<7.5 cm, 0.10 m^3/ha of dead stumps, 2.62 m^3/ha of dead branches and 1.07 m^3/ha of stumps. Adding together the volumes of these categories, we obtained 5.3 m^3/ha for snags, 6.87 m^3/ha for logs, and 0.10 m^3/ha for dead stumps, for a total of 12.27 m^3/ha of deadwood. As reported by Crecente-Campo et al. [21], the average volume of wood necromass in the Spanish forests was 8 and 10.5 m^3/ha according to the third and fourth Spanish National Forest Inventories (SNFI3, 1997-2007; SFNI4, 2008-2013). Therefore the volumes recorded in this research far exceed the national average volume estimated from the inventories, in fact almost 22.5 m^3/ha of deadwood have been estimated, but it was distributed differently according to the class of accessibility. This situation could be due to several causes, among these, the combination of slope, cattle grazing and frequent rain and snow phenomena may have favored the rolling and the accumulation of deadwood from mountain to valley, then towards the roads; and the deadwood might have been collected by man in the access classes furthest from the road, because less visible.

The values of carbon stored in deadwood within the sampling areas far exceed those estimated by Gasparini and Di Cosmo [22] and by Vallauri et al. [23] for the Italian beech forests, that is 3.1 t/ha and 5 t/ha respectively. The stored carbon values depend on the volume of deadwood, therefore these also decrease as the distance from the access road to the forest increases. These high carbon accumulation is one of the positive consequences resulting from the presence of high quantities of deadwood in the forests.

5. Conclusions

In conclusion, both the quantity and the quality of the deadwood in the investigated areas were determined. The deadwood, and therefore the amount of stored carbon, were higher than those reported in the Spanish and Italian national forest inventories. Specifically, they were also higher than the average reported for Riojan beech forests, and also compared to the averages reported in other Italian and European studies in the literature. All decomposition classes except the first were found and this suggests minimal anthropogenic pressure on the deadwood within the studied beech forests. The lack of anthropic disturbance in fact leads to the natural decomposition of this important ecosystem component. In any case it is desirable a compliance with the regulations in force, so that, in the absence of specific authorization, the deadwood is not removed but left to decompose naturally.

Author Contributions: conceptualization, A.L.M., C.P.C. and I.C.; methodology, A.L.M., C.P.C. and I.C.; software, A.L.M.; validation, A.L.M. and E.Z.; formal analysis, A.L.M. C.P.C. and E.Z; investigation, I.C.; resources, C.P.C. and A.L.M.; data curation, I.C., E.Z. and A.L.M.; writing—original draft preparation, I.C.; writing—review and editing, E.Z. and I.C.; supervision, I.C. and A.L.M.; funding acquisition, C.P.C.

Funding: This research was funded by Spanish Ministry of Science, Innovation and Universities, AGL2016-76769-C2-2-R.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Olano, J.M.; Peralta de Andrés, J. 9150 Hayedos calcícolas medioeuropeas del Cephalanthero-Fagion. En: VV.AAaa., *Bases ecológicas preliminares para la conservación de los tipos de hábitat de interés comunitario en España.* Madrid: Ministerio de Medio Ambiente, y Medio Rural y Marino, 2008, pp. 26-27.
2. Harmon, M.E.; Sexton, J. Guidelines for Measurements of Woody Detritus in Forest Ecosystems. Publication No. 20 WA: LTER Network Office, University of Washington., Seattle, 1996, p. 73.
3. Densmore, N.; Parminter, J.; Stevens V. Corse debris: Inventory, decay modeling, and management implications in three biogeoclimatic zones. *BC j. ecosyst. manag*. **2004** *Vol.5*, No.2, pp. 14-29.
4. Gasparini, P.; Di Cosmo, L.; Pompei, E. Inventario Nazionale delle Foreste e dei serbatoi forestali di Carbonio INFC 2005. *Secondo inventario forestale nazionale italiano. Metodi e risultati dell'indagine integrativa.* Trento, Ministero delle Politiche Agricole, Alimentari e Forestali, Corpo Forestale dello Stato, 2005.
5. Woldendorp, G.; Keenan, R.J.; Ryan, M.F. Coarse woody debris in Australian forest ecosystems. *A report for the National Greenhouse Strategy*, Module 6.6 (Criteria and Indicators of Sustainable Forest Management) **2002**.
6. Stokland, J.N.; Tomter, S.M.; Söderberg, U. Development of Dead Wood Indicators for Biodiversity Monitoring: Experiences from Scandinavia. EFI Proceedings, 2004; p. 211.
7. Fan, Z.; Larsen, D.R.; Shilley, S.R.; Thompson, F.R. Estimating cavity tree abundance by stand age and basal area, Missouri, USA. *Forest Ecol Manag* **2003**, *179*, pp. 231–242.
8. Fan, Z.; Shifley, S.R.; Thompson, F.R.; Larsen, D.R. Simulated cavity tree dynamics under alternative timber harvest regimes. *Forest Ecol Manag* **2004**, *193*, pp. 399–412.
9. Böhl, J.; Brändli, U.B. Deadwood volume assessment in the third swiss national forest inventory: methods and first results. *Eur. J. For. Res*. **2007**, *126*, pp. 449–457.
10. Nagaike, T. Snag abundance and species composition in a managed forest landscape in central Japan composed of Larix kaempferi plantation and secondary broadleaf forests. *Silva Fenn.* **2009**, *43*, pp. 755–766.
11. De Long, S.C.; Sutherland, G.D.; Daniels, L.D.; Heemskerk, B.H.; Storaunet, K.O. Temporal dynamics of snags and development of snag habitats in wet spruce-fir stands in east-central British Columbia. *For. Ecol. Manag*. **2008**, *255*, 3613–3620
12. Intergovernmental Panel on Climate Change, IPCC Guidelines for National Greenhouse Gas Inventories. Institute for global environmental strategies, Hayama, Japan, 2006, pp.4.83.
13. INE – Insituto Nacional de Estadística. Available online: https://www.ine.es/ (accessed on 10 December 2019)
14. Gobierno de La Rioja. Available online: https://web.larioja.org/ (accessed on 15 December 2019)
15. Hunter, M.L. *Wildlife, forests, and forestry: principles of managing forests for biological diversity*, Prentice Hall, 1990.
16. Morelli, S.; Paletto, A.; Tosi, V. Il legno morto dei boschi: indagine sulla densità basale del legno di alcune specie del Trentino. Forest@ **2007**, 4, pp. 395-406.
17. Castellani, C. Tavole stereometriche ed alsometriche costruite per i boschi italiani. Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura, Trento, 1982.
18. Sipala, B. L'importanza della necromassa legnosa: caratterizzazione quali-quantitativa e variabilità del legno morto in relazione all'accessibilità delle faggete gestite del Parco Nazionale d'Abruzzo, Lazio e Molise. Tesi di Laurea Magistrale, Università degli Studi della Tuscia, Viterbo, 09/2018.
19. Behjou, F.K.; Lo Monaco, A.; Tavankar, F.; Venanzi, R.; Nikooy, M.; Mederski, P.S.; Picchio, R. Coarse Woody Debris variability due to human accessibility to forest. *Forests* **2018**.
20. Cuarto Inventario Forestal Nacional – La Rioja; Gobierno de España, Ministero de Agricultura, Alimentación y Medio Ambiente; Gobierno de La Rioja; Dirección General de Desarrollo Rural y Política Forestal - Área de Inventario y Estadísticas Forestales, Madrid, 2013.
21. Crecente-Campo, F.; Pasalodos-Tato, M.; Alberdi, I..; Hernández, L.; Ibañez, J.J.; Cañellas, I. Assessing and modelling the status and dynamics of deadwood through national forest inventory data in Spain. *Forest Ecol Manag* **2016**, *360*, pp. 297-310.
22. Gasparini, P.; Di Cosmo, L. Forest carbon in Italian forests: Stocks, inherent variability and predictability using NFI data. *Forest Ecol Manag* **2015**, *337* pp. 186-195.
23. Vallauri, D.; André, J.; Blondel, J. Le bois mort, un attribut vital de la biodiversité de la forêt naturelle, une lacune de la forêt gérée. Rapport WWF, France, Paris, 2003.