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DEAD WOOD – AN IMPORTANT ISSUE FOR FOREST BIODIVERSITY CONSERVATION

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Abstract. The importance of deadwood in forest ecosystems is widely recognized today and it is used as indicator for the sustainable management of forests. The purpose of researches carried out in five natural reserves and managed Romanian forests was to determine and compare the amount, size, distribution and decay classes of their deadwood. The data obtained in the mixed beech coniferous and beech old growth forests can be used as reference values for the natural dynamic of deadwood and can contribute to set the rules for the restoration of deadwood in forest management.

Introduction

In Europe, for an appropriate and sustainable management of forest ecosystems, a reliable monitoring system is an undeniable necessity. The monitoring instruments used at European level are the National Forest Inventories and ICP scheme for monitoring the effects of air pollution on forests. In time, after a series of important events for the forest ecosystems conservation, like the Convention on Biodiversity Conservation, Kyoto Conference, The Ministerial Conferences on the Protection of Forests in Europe (MCPE), new variables became necessary for assessing the state of forests and for establish future ways of action for the best management of these forests.

After a period of concerted scientific efforts, criteria and indicators for sustainable forest management were set; between them, dead wood was chosen as an important indicator for the biodiversity conservation criteria (indicator 4.5, adopted by the MCPE). It is also used as indicator in forest certification standards, and it already became a recent added variable in some European National Forest Inventories.

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For a long time, in managed forests, the standing and lying dead wood was considered useless and even dangerous for the forest health, and it was removed during special cutting interventions called "sanitary measures"; plus, the trees are cut and removed before reaching the old stage, and so, the dead wood amount in managed forests is drastically reduced in comparison to natural forests. In the last decades, a completely changed approach occurred, and the crucial importance of dead wood in the forest ecosystem structure and functions is widely recognized.

Most often, dead wood components are standing dead or dying trees, fallen logs, twigs and branches, stumps or even components of mature living trees like branches, bark, twigs, roots. Veteran trees, partially rotten, with holes and cavities are also very important for maintaining forest ecosystem structure and functions. The factors which create deadwood in natural forests are natural selection, aging process finalized with natural mortality and various disturbances like windthrows, droughts, fungal or insect disease, fires. In managed forests, clearing and cutting activities came to complete the factors list.

Dead wood is playing a complex role in forest ecosystems: from reducing erosion and maintaining slope and soil surface stability, to biodiversity conservation, forest regeneration (seedbed for plants) and carbon storage.

Dead wood, especially logs in different stages of decay, lying across slope, are reducing soil and precipitation water movement down slope, i.e. reducing erosion (Mccombe W., Lindenmayer D., 1999). Large logs have a geomorphologic role in both terrestrial and stream ecosystems. In terrestrial ecosystems they accumulate soil and litter on their upslope side creating new habitats for different forest species and speeding decomposition. Logs can modify stream geomorphology creating a chain of new rapidly flowing water and pools, which means new habitats for aquatic species too (Stevens, 1997).

Another notable contribution of decaying dead wood is to nutrients recycling process, which assure the forest continuity; this process plays also an important role in the world carbon cycle and climate change. Dead wood, along with trees, bushes litter and soil represent a carbon pool for a certain period, longer or shorter, depending on the dead wood species, dimensions and climate conditions. If the climate is cool, the decomposition of the deadwood is slow (like in temperate and boreal forests) and carbon can remain sequestered for centuries. Anyway it is sure that dead wood is a more suitable carbon pool in comparison with fast-growing rotations of plantations (proposed as solution after the 1992 Kyoto Protocol) because these are accumulating fast carbon, but it's storage is very short, only a few years; after that the wood is transformed into paper and other quickly degradable products. In addition it can be said that old-growth forests and dead wood are better carbon keeper in comparison with the young forests that replace them.

The decaying process of dead wood has a fundamental influence not only in forest sites geomorphology or carbon storage, but on forest biodiversity too. Decaying takes a long period of time and has a sequence of phases depending on species, position, age of dead trees and climatic conditions. For every phase, different associations of fauna populations are specific: during the first phase, which is shorter, insects and fungi (primary saproxylic species) are colonizing the still hard dead wood (Dudley, Vallauri, 2004; Christensen, 2005). In the second phase, longer than the first one, new species came to settle: secondary saproxylic represented by predators of primary once or partially decomposed matter consumers. This phase is the richest in fruiting fungi, including numerous red listed species (Heilmann-Clausen, Christensen, 2003). In the last phase the decaying process is finished and the scavenging species (millipedes, springtails etc.) are mixing the wood residues with the forest soil. The bryophytes species prefers both second and last phases of decomposition and their diversity is high if they have sufficient air humidity (Soderstrom, 1988).

Standing and lying dead wood assure feeding sources and proper places for nesting, mating, loafing and food storage for a large variety of animal species from amphibians and reptiles to birds and mammals (Rahman, M., et al., 2008).

To summarize, species depending on all kinds of dead wood are: bacteria or algae (especially in young dead trees), bryophytes, lichens, fungi, ferns, tree plants, even flowering plants (on large woody debris), invertebrates, woodlice, millipedes, flies, hoverflies, xylophages beetles and their predators, large longhorn beetles, birds from large raptors, owls, to species who bore like woodpeckers or species which take over nesting holes, reptiles, mammals like squirrels, martens, wild cats, dormice, wood mice, shrews, bats, deer, even bears (if the snags have major cavities large enough); in rivers and streams, coarse woody debris offer habitat for algae, fly larvae and breeding fish.

Once the importance and the role of dead wood established, data regarding its volume and its inhabitant species started to be gathered in numerous countries in Europe and all over the world. In this context, the deadwood related researches in Romanian forests were considered appropriated. Researches in forest reserves are important because they can provide reference values regarding the deadwood and precious information about the related biodiversity that can later be used in the management of other forests.

1. Materials and methods

Researches were conducted in five sites, three protected natural old growth forests, and two managed forests. The forests from the natural reserves are one mixed beech-coniferous forest - Slătioara, located on the east side of Rarău Mountain, at 800 – 1300 m altitude (Suceava county) and two beech dominated

forests, Suharău (340 m altitude) and Humosu (450 m altitude) located in Ibăneşti hills (Botoşani county), and respectively Dealul Mare (Iaşi county). The managed forests are mixed beech-coniferous forests, more than 80 years old, one located in Obcina Voroneţului, near Gura Humorului town, at 470 m altitude, and the other, Rîşca, located in the east side of Stânişoara Mountains, at 600 m altitude (both in Suceava County).

Data were collected in randomly distributed plots of variable dimensions, from 225 m^2 to 1.6 ha. Dead wood is considered in this study the standing deadwood or snags and lying deadwood with more than 5 cm diameter. For the standing trees the breast height diameter and height were measured and for the lying deadwood pieces, top, bottom diameters and length. For the lying pieces, the volume was determined using the formula for a frustum of a cone (Roibu, 2010) and for the standing trees, the volume's double logarithmic equation (Giurgiu, Drăghiciu, 2004). For every piece of dead wood the decay class (Christensen, Hahn, 2003) was determined and registered (table 1). The first two classes of decay correspond to the first phase of the decomposition process described above, the next three to the second phase, and the last class to the last phase.

Tab. 1 – Decay classes (Christensen, Hahn, 2003)

Decay Class	Bark	Twigs and branches	Softness	Surface	Shape
1	intact or missing only in small patches, > 50%	present	hard or knife penetrate 1-2 mm	covered by bark, outlineintact	circle
2	missing or < 50% only branches>3 cm	present	hard or knife penetrate less than 1 cm	smooth, outline intact	circle
3	missing	missing	begin to be soft, knife penetrate 1-5 cm	smooth or crevices present, outline intact	circle
4	missing	missing	soft, knife penetrate more than 5 cm	large crevices, small pieces missing, outline intact	circle or elliptic
5	missing	missing	soft, knife penetrate more than 5 cm	large pieces missing, outline partly deformed	flat elliptic
6	missing	missing	soft, partly reduced to mould, only core of wood	outline hard to define	flat elliptic - covered by soil

2. Results and discussions

As expected, the difference regarding the amount of dead wood of the managed and protected forests is significant. In Slătioara forest reserve, the amount of deadwood reach the value of 163.69 m^3/ha, and in Suharău beech forest 186.83 m^3/ha. These values are comparable with the ones resulting from similar researches in Romania and other European countries.

The amount of dead wood was determined in other Romanian natural forests too: in Izvoarele Nerei beech reserve, it varies from 50 m^3/ha at high altitude to 223 m^3/ha at low altitude, with an average of 87 m^3/ha (Tomescu, Târziu, Turcu, 2011). According to another research located in the same reserve the amount of dead wood varies between 78 and 121 m^3/ha (Radu, 2006). For Şercaia, Gemenele, and Iauna Craiova forest reserves, the dead wood range from 49-128 m^3/ha (Vrska et al., 2000).

In Poland, in Bialowieza forest, protected since the 1300's as a hunting reserve, the dead wood amount varies between 87 and 160 m^3/ha, and in Havesova, beech forest reserve from Poloniny National Park, Slovakia, an average of 121 m^3/ha of deadwood was found (Saniga, Schütz, 2001). In France, in the well known Fontainebleau forest reserve, protected from logging since 1853, the deadwood volumes are 142 to 256 m^3/ha (Mountford, E., 2002). In United Kingdom, at Ridge Hanger, beech forest reserve, the measured deadwood volume was 273 m^3/ha (Christensen, Hahn, 2003).

A special situation occurs in the other studied beech protected forest, Humosu, where the deadwood amount is smaller, 89.6 m^3/ha because a part of it, infested with *Lymantria dispar* eggs, was removed with the Romanian Academy approval for preventing an outbreak. A supplementary amount was illegally removed by the local population, regardless the protection regime.

In Slatioara from the total amount, 129.22 m^3/ha was fallen wood and the rest standing dead trees. In Suharău, the amount of lying dead wood is 166.07 m^3/ha, and in Humosu 54.54 m^3/ha.

For the managed forests the amount of total dead wood varies according the human impact intensity: Rîşca forest is far from any human settlement and the amount of deadwood is important (53.23 m^3/ha of which 45.01 m^3/ha fallen deadwood), while in Humor forest the deadwood value is 20.94 m^3/ha (with 14.15 m^3/ha lying deadwood). The reason for this diminished value is firewood removal by tourists from the nearby camping area and by Humor inhabitants.

The national average amount of dead wood in European managed forests is considerable diminished compared with natural forests and varies from 0.6 m^3/ha in Austria to 12 m^3/ha in Switzerland (table 2).

Tab. 2 – Amount of deadwood in European managed forests (national averages)

Country	**Dead wood volume (m^3/ha)**	**Country**	**Dead wood volume (m^3/ha)**
Austria	0.6	Belgium	9.1
Germany	1-3	Finland	2-10
France	2.2	Luxembourg	11.6
Sweden	6.1	Switzerland	12

(Dudley, Vallauri, 2004)

In the natural old growth beech coniferous mixed forest, Slătioara, the deadwood has diverse sizes and the volume is distributed in all diameter classes (figure 1). The best represented are of course large diameter classes. The volume of deadwood with 34 to 46 cm in diameter represents 33% of the total, and the one with diameters over 54 represents another 40%.

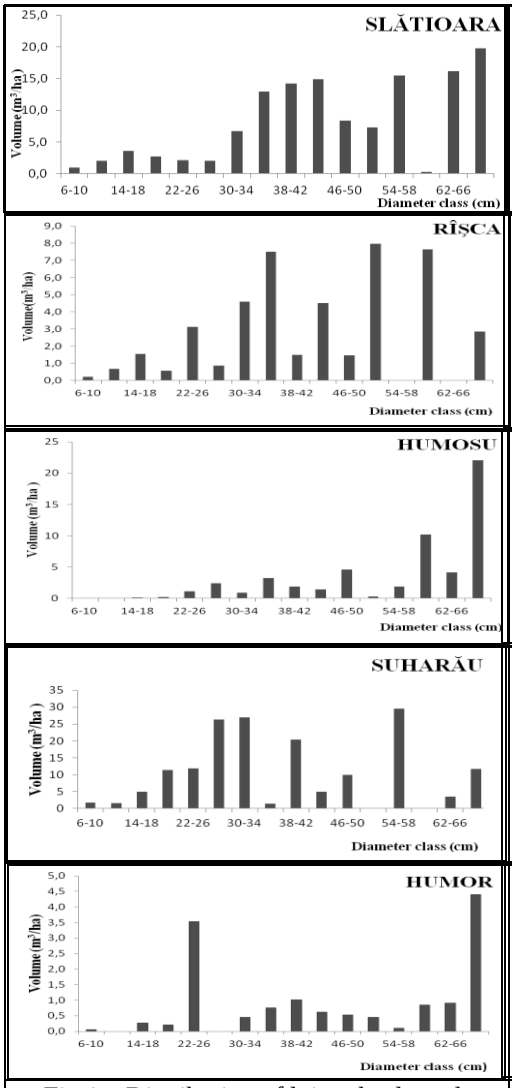

Fig.1 – Distribution of lying deadwood volume by diameter class

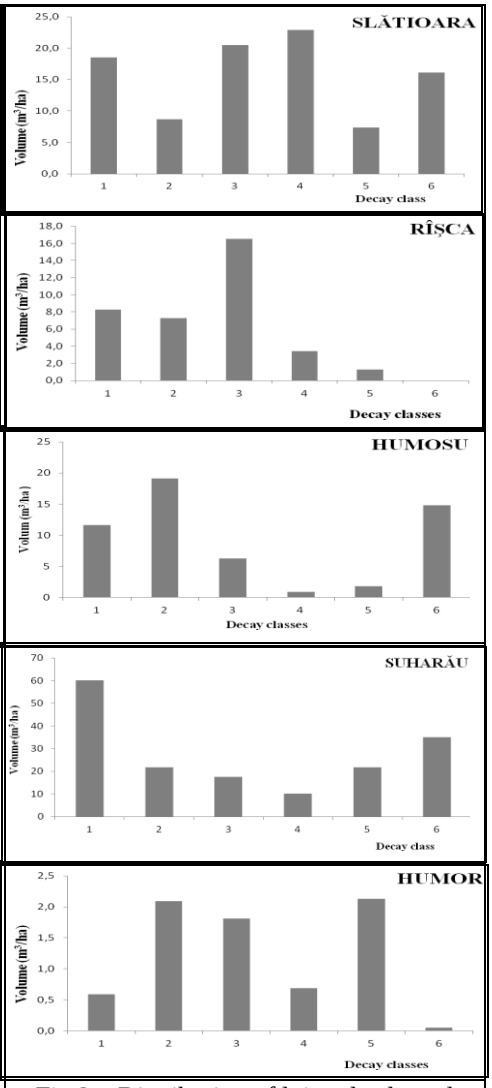

Fig.2 – Distribution of lying deadwood volume by decay class

This is very important because large trees are the most valuable for biodiversity conservation. A similar volume distribution by diameter can be observed in Suharau beech reserve where the volume of logs over 54 cm diameter is 35% of total.

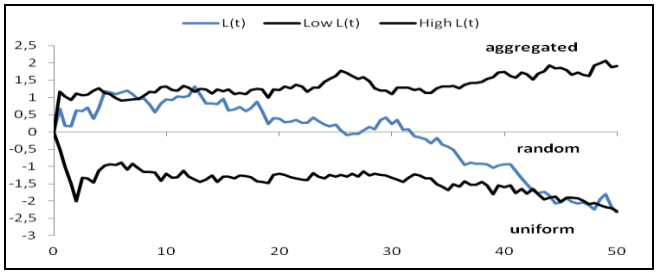

Fig. 3 - Ripley function for the deadwood spatial distribution in Suharău forest

In Humosu forest, the volume of the over 66 cm diameter class represents 40% of the total amount because of the stumps remained after sanitary measures.

For Rîşca managed forest, the 34-38 cm, 50-54 cm and 58-62 cm diameter classes have the most important volumes, each reaching around 13% of total amount indicating possible local wind felling favored by the annosum root rot frequent in the area. The total amount of deadwood over 40 cm in diameter is 25.94 m^3/ha amount considered enough for maintaining diverse saproxylic species. In Humor the 22-26 diameter class is the best represented, with 21% of the total amount, indicating a possible past wind felling. Similar to Humosu, the stumps left after thinning or illegal wood removal (over 62 cm), have a notable volume which represents 31% of the total amount. Only in Humor the amount of dead wood over 40 cm diameter is 8.87 m^3/ha (under 20 m^3/ha) with negative consequences for biodiversity conservation.

Regarding the distribution of deadwood volume by decay classes, the most balanced is the Slătioara distribution, the dead wood exists in all decomposition stages illustrating a normal and healthy functioning of the forest ecosystem processes. In Suharău, the transition stages are not very well represented, but the situation will improve because 36% of the volume is in the first class of decomposition and will decay. In Humosu the sanitary removal of dead wood can be easily noticed, the intermediate 3, 4 and 5 decay classes having a small volume each. But in this case too, the first two classes are well represented (56%), promising an improvement of the situation. In Rîşca forest more than one third of the dead wood volume (36%) is in the third decay class, indicating a past disturbance. The small actual amount of dead wood in the first decomposition class

for Humor forest is the proof of the human (especially tourists) pressure. Instead, the rest of the deadwood volume has a balanced distribution.

Along with the size, volume and decay class of deadwood, the spatial distribution has an influence on biodiversity too. Therefore, the spatial pattern of deadwood was studied in Suharău natural beech forest. The distribution, according to the Ripley function is a random one (L(t)), with partial tendency to aggregation at low scale and to a uniform distribution at larger scale (figure 3).

The spatial pattern of the standing and dying deadwood in this natural forest reserve (figure 4) illustrate the general random distribution with greater accumulations near canopy gaps created by natural selection or wind felling.

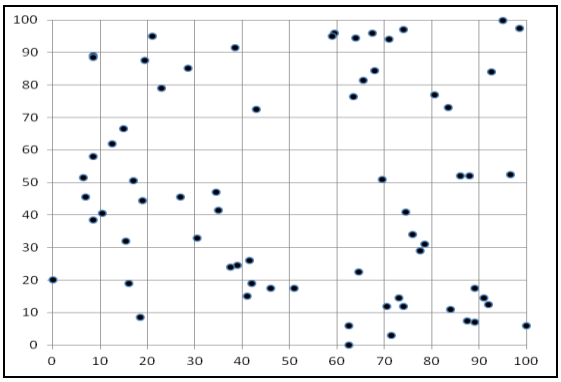

Fig.4 - Spatial distribution of stumps and logs in the 1 ha plot, Suharău forest reserve

In natural forest reserves like Slătioara or Suharău according to the amount and decomposition stage of dead wood, can be assumed that proper conditions exists for the existence of diverse invertebrate fauna, bryophytes and fungi species, including red listed ones similar with the species found in Izvoarele Nerei forest reserve (Berducou, et al., 2006, in Tomescu, Târziu, Turcu, 2011).

In Europe, the State of Europe's Forests 2011 report indicate that the amount of deadwood varies a lot according to forest types, standing volume of the stands and forest management. A slightly increment of deadwood volume was observed in most of Europe's regions in the last 20 years, the most likely as a result of the reorientation towards a more nature-oriented management (Larsson, 2011).

There is a lack of information regarding the most appropriate volume thresholds, size, decay class and distribution of dead wood for different forest types and management intensity. Until this lack of information will be filled up, the specialist offer some general values considered acceptable in the managed forests for the moment: at least 20-30 m^3/ha (Dudley, Vallauri, 2004). For biodiversity

conservation aims, forest areas must contain at least 40 m³/ha of dead wood for sheltering diversified communities of saproxylic organisms (Coleoptera), and for the conservation of invertebrate red list species, fungi, and birds, in forests must remain at least 20 m³/ha of dead wood with a diameter over 40 cm (Winter, 2008).

Currently, in our country, the on-going National Forest Inventory collects data concerning the deadwood volume, but information about the situation at national level is not available yet.

Conclusions

The views that a clean forest, without dead wood is a healthy and more stable forest, that deadwood brings fire and disease, that deadwood implies a risk for tourists and visitors, and that a forest with downed trees is ugly and poorly managed, are today obsolete.

The role of dead wood in maintaining the proper functioning, stability and biodiversity of forest ecosystems is widely recognized.

Researches carried in five Romanian forests, three old growth forest reserves and two managed forests shows that the amount of dead wood is considerably higher in the natural forests, and it decreases along with the human impact intensity augmentation: in Slatioara reserve, the dead wood amount is 163.69 m^3/ha, in Suharău beech reserve 186.83 m^3/ha, in comparison with the managed forests where the amount is 53.23 m^3/ha for a moderate human impact and 20.94 m^3/ha for a greater human pressure.

A special situation occurs in the other beech protected forest, Humosu, where the deadwood amount is smaller, 89.6 m^3/ha because a big part of it, was removed with the Romanian Academy approval for preventing an outbreak.

The values obtained for natural forests are important as reference values in the future management of forest ecosystems.

The on-going National Forest Inventory will play an important role in collecting data about deadwood for sketching an image about it at national level. In the future, the management plans will contain deadwood data too. This will be the base for determining the most suitable management of dead wood.

The steps to be followed in the future are: first, completing the researches for determining the amounts, size, decay class and distribution of the dead wood that must be kept in different types of managed forests so that the deadwood could fulfill all his functions in the forest, including in biodiversity conservation; then, a standardized inventory and monitoring system is indicated to be implemented in all the European countries, including Romania, so that the management measures applied for the dead wood to be effective and all the information concerning deadwood – comparable.

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