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DEADWOOD ACCUMULATION IN DECIDUOUS DOMINATED FORESTS

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Deadwood is important structural element of forest ecosystem. The amount of deadwood started significantly to decrease in Lithuanian forest due to intensification of forestry. During the last year high problematics creates deadwood demand for energetic purposes. Protection of deadwood is one of mostly important modern challenges as it valuable stock as well as the habitat for endangered deadwood related species. Under conservationists the volumes of deadwood are far away from desired. The aim of study to evaluate cumulated amounts of deadwood in premature and mature deciduous dominated forests with different management status: intensive management, recently converted to conservation status and stands with long conservation history. The study performed in Bukta forest, that represent complex of described above conservation scenarios. The deadwood and stand was evaluated in systematically selected by GIS methods circle study plots with 500 m² area. Total evaluated area exceeds 3500 ha and study design consist of 261 study plots. During the analysis we evaluate landscape level factor effect (e.g. edge effect) on deadwood accumulation. The results shows different deadwood amounts due to different management scenarios and landscape.

Key words: deadwood, deciduous forest, Lithuania.

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INTRODUCTION

The amount of deadwood in forests has been on a sharp decline ever since the beginning of intensive forestry in the second half of XIX century. Due to the reduced amount of old growth and increased fragmentation, a number of saprophytic organisms' conditions deteriorated, which resulted in them becoming sparse and endangered. Species that were once common are now rare, as their population became small and fragmented (Scheidegger & Goward 2002). The intensified use of cutting waste for biofuels' production has further worsened the problem recently.

The most pressing matters regarding the protection of various species is reconciling both environmental and economic interests, as well as determining the minimum amount of deadwood required to keep the species from extinction and retain biodiversity. Every species associated with deadwood has different needs - some require more of it, while others less, which is why it is important to find the optimum quantity. Pentilla (2004) did not find any endangered species of mushrooms in woods with less than 20 m³/ha of deadwood. This number should be held as important as it is when rare species would begin to appear. Furthermore, it should be noted that the number might be smaller in locations with no recent forestry activity and with long continuity of the forest. After looking into other researchers' propositions for the amount of minimum deadwood in a wood, J. Muller and R. Butler (2010) suggested to leave 30-50 m³/ha of deadwood for plain oak and beech forests. Sustained presence of various deadwood is as important as the continuity of a forest itself.

It is necessary to keep in mind various researchers determine differently what to call coarse deadwood with respect to the minimum diameter, thus one should be careful when evaluating the numbers each author provides. It is often the case the same researchers specify different minimum diameters for various deadwood components (wind thrown trees, snags and stums).

It is currently impossible to perform a comprehensive analysis on deadwood in Lithuanian woods due to lack of published data about the quantity of it. Furthermore, the data available, especially the one regarding managed forests, is often fragmentary and limited to search for rare species or episodic investigations.

The protection of deadwood is one of nowadays forest environment protection concerns as it is a valuable material which gets removed from the forests for economic reasons, but at the same time, it is a habitat for a number of species that have not reached their optimal quantity even in conservation forests.

The aim of this investigation is to determine the present amount of deadwood in multi-purpose mature and still maturing deciduous and mixed (where at least 50% of the trees are deciduous) forests (household, forests recently converted to protected, natural conservation forests).

Fig. 1. Map of the experiment place.

MATERIAL AND METHODS

This research aims to investigate maturing and mature deciduous and mixed (at least 50% of deciduous trees) woods.

The investigation, in which both the quantity and the quality of multi-purpose forests' deadwood was evaluated, took place in Bukta forest, which is located in Marijampolė forest enterprise Bukta forest district Žuvintas biosphere's reserve (Fig. 1.). Bukta forest was chosen as it can represent every type of mixed and deciduous forest – managed, recently made protected and already protected.

The investigation was conducted in temporary, constant diameter circle 500m^2 plots, with horizontal radius of 12.62m. The plots were chosen after an analysis of Bukta forest using the GIS method. The centre of the plot was determined by calculated coordinates using a GPS device. The full area of investigation was 3500 ha. In total, 261 plots were used to evaluate deadwood quantity.

The plots were chosen in maturing and mature deciduous and mixed (more then 50% of the trees are deciduous) woods. In the study, mature and maturing woods were regarded as woods from any group of forests, where mature and maturing trees have reached the age according to IV forest group wood norms: oak starting 111 years; pine, larch, ash, maple, beech and elm starting 91 years; spruce starting 61 years; hornbeam, birch, black alder, linden starting 51 years; aspen starting 31 years.

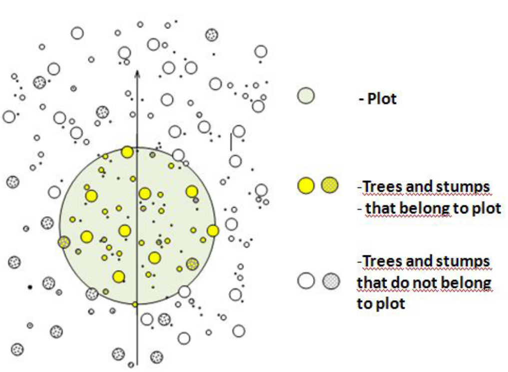
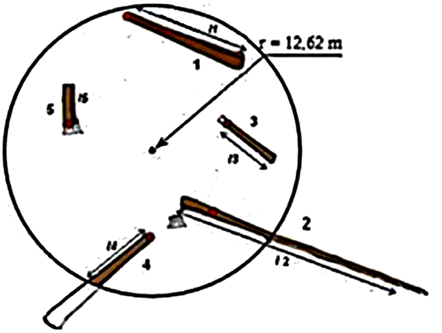


Fig. 2. Plot covering 500m² and trees and stumps that belong to it.

A tree's inclusion into a plot was determined strictly on its diameter's place of measurement (at 1.3m height from the neck of the root), regardless of the tree's trunk location (Fig. 2). A stump's inclusion in a plot was determined in the same way – the stumps were assigned to a plot depending on the smallest diameter's on the stump value. A tree's centre was determined by the point where calliper legs touch with the trunk. A measuring tape was used to find the exact boundary of a plot.

Fallen branches, cut down and left or broken off trees, their trunks, logs, parts of logs and wood in various stages of decomposition were determined as part of the plot using merchantable trunk wood left after chopping recording method (Kuliešis et al. 2009). In this principle, every branch with diameter bigger than 10 cm at the thinnest end, every after-cut trunk at 1.3m height with a bigger than 10cm diameter and every logs, their parts and wood in various pieces are wood bigger than 10cm in diameter at the thinnest end are counted in as a part of a plot (Fig. 3).



1 – log that is part of the plot area,
2 – stem that is part of the plot area
3 – log that is part of the plot area,
4 – a part of a log that is part of the plot area,
5 – stump that is part of the plot area,
• – diameter measure location
l – stem's (log's) length measurement
Fig. 3. Wood that is counted in as a part of a plot area.

The wood's species composition, age, stocking level and site types was set for each of the plot. The age was determined using age drill.

Every tree and stump that met the criteria, no matter whether it was green, dead or in any stage of decomposition was measured in the plot: every tree with longer than 10cm diameter at 1.3m heigth, every stump longer than 10cm diameter at the neck of the root, every branch with diameter wider than 10cm at the thinnest point, every stem left after cutting (with the top or without, can be cut into pieces) with larger than 10cm diameter at 1.3m height, every log diameter larger than 10cm a the thinnest point, their parts or wood at any stage of decomposition and its parts.

Tree species, storey, condition, diameter and height was determined for each tree and stump in the plot. For trees, windtyhrown trees and stems, the diameter was measured at 1.3 height from the stump, for stumps the smallest diameter above the ground level was taken, for logs, branches and various decomposing deadwood on the ground the diameter was taken at the thinnest end of it or in another place, depending on the object measured. The diameter was measured with the help of callipers at 1cm accuracy. The height measurements were taken with a "Silva Clino Master" altimeter. The heigth and diameter of the trees were determined using the methods described in The Forest Taxation (Repšys 1994), The National Forest Inventory Work Rules (Kuliešis et. al. 2009) and wood volume tables (Petrauskas et. al. 2010).

During the investigation, an evaluation on landscape's influence on the formation of deadwood was carried out as well. The distance between the plot and edge of the forest, drainage system, road and clearcut area was measured. The landscape's influence was evaluated only if the drainage system, road or clearcut area was less than 200m, edge of the forest less than 500m away from the centre of the plot.

Throughout the analysis, standing dead trees, snags windthorwn trees, stumps, fallen branches and cut down and abandoned wood and wood and its parts at any stage of decomposion were referred as deadwood:

1. Dead trees – whithered standing trees with any branches. Trees with no green needles or leaves during time of vegetation and with bark that is beginning to die were also assigned to this category.

2. Snags – a part of a hacked tree's stem, which is standing and is at least 1m tall. Trunks that are still standing and are both higher than 1m and have no branches or a single branch were a part of this category.

3. Wind thrown trees – thrown down, recumbent or tilted at 45° tree trunks.

4. Stumps – a part of a hacked tree's stem that is shorter than 1m.

The stage of decomposion was determined for deadwood inside of each plot. The stage of decay for ground wood (windthrown trees, fallen branches, hacked and abandoned trees, their stems, logs, their parts and various other parts of wood left on the ground at various stages of decomposion) was evaluated on a 5 point scale (Waddell, 2002):

1 – solid, recently fallen wood that has no started to decompose yet, lean branches with bark;

2 – mostly solid fallen wood, alburnum starting to rot, somewhat soft, cannot saparate the wood using hands, lean branches have mostly fallen off, those that are left would have their bark peeling off;

3 – large, hard pieces of wood can mosly be saparated by hand, the ends of large branches cannot be pulled off easily from the fallen tree;

4 – core is rotten, log does not support its own weight but retain their shape, the ends of large branches can be easily pulled away.

5 – nearly fully rotten, log does not maintain its form, is soft and crumbly.

The stages of decay were determined in the same way for standing dead trees, snags and stumps.

The data collected during the investigation was processed and analysed using "MS Excel" and "Statistika" software. Factor influence was analysed using the F (ANOVA) method. The method examines whether the differences between group averages are reliable. If the reliability level for F criteria is $p<0.05$ (95%), the factor influence is reliable, thus indicating the factor has a significant influence.

RESULTS AND DISCUSSION

During the analysis, both the quantity and quality of the deadwood were determined. A landscape's and growth condition's role in formation of deadwood was established and evaluated as well.

After analysis of growth conditions, it was found that the site humidity had a significant role in the creation of deadwood ($F = 9.62$, $p < 0.05$). The amount of deadwood found in a plot was between 11 and 21 units, depending on the site humidity. Most of the deadwood had accumulated in peat soils (average of 21 units per plot), slightly less in constantly wet soils (average of 17 units per plot) and temporary wet soils (average of 16.5 units per plot), while the lowest amount was found in normal humidity soils (average of 11 units per plot) (Fig. 4). The amount of deadwood in normal humidity soils was found to be nearly twice lower than in the peat soils. As the humidity of the soil increases, the trees resistance to negative abiotic and biotic agents decreases and the amount of deadwood increases.

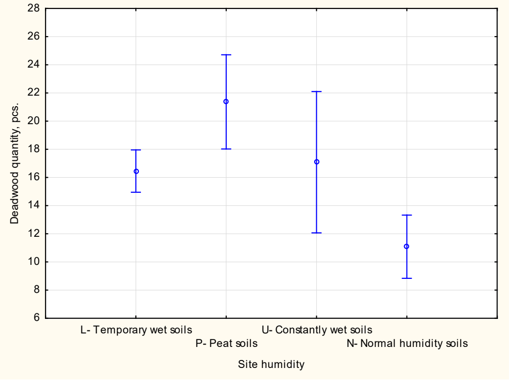


Fig. 4. Distribution of deadwood by site humidity.

During the analysis, it was found that site fertility had no significant impact on the formation of deadwood ($F = 0.768$, $p > 0.05$). When looked at site type (humidity and fertility) role in the formation of deadwood, it a statistical significance was found ($F = 4.27$, $p < 0.05$) in regards to the amount of deadwood evaluated (Fig. 5.). As the soil's humidity and fertility increases, so does the amount of deadwood, from 9 units per plot when the soil is temporary wet and infertile, to 21.5 units per plot at fertile peat soils.

An analysis of the distribution of the total amount of deadwood by the forests groups identified no significant effect of the type of forest on the amount of deadwood present ($F = 0.85$, $p > 0.05$).

However, it was discovered that the predominant tree species had a significant effect on the overall quantity of deadwood ($F = 5.87$, $p < 0.05$). The biggest amount of deadwood forms in places where softwood deciduous trees are predominant, while the smallest – in places with hardwood deciduous tree prevalence. Depending on the prevalent type of wood, deadwood count ranges from 7.5 units per plot to 20.5 units per plot

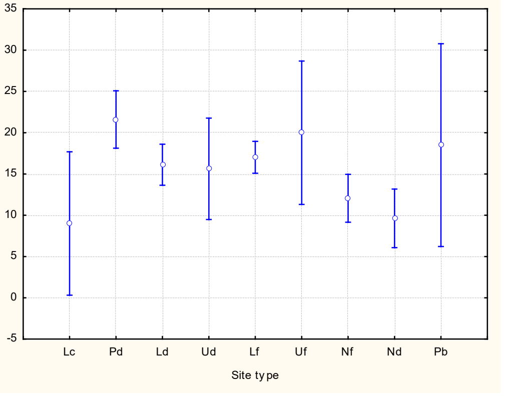


Fig. 5. Deadwood distribution by site type (Lc- temporary wet fertile soils; Pd- peat very fertile soils; Ld- temporary wet very fertile soils; Ud- constantly wet very fertile soils; Lf- temporary wet particularly fertile soils; Uf- constantly wet fertile soils; Nf- normal humidity particularly fertile soils; Nd- normal humidity very fertile soils; Pb- peat infertiler soils.

(Fig. 6). The largest quantity of deadwood can be found in woods with a high number of black alder *(Alnus glutinosa)* and the smallest in woods with a large number of common hornbeam *(Carpinus betulus)*. Such distribution results because of each species of tree's individual requirements of the soil, especially its humidity.

A further analysis was carried out on the distribution of deadwood depending on the four elements of landscape: the distance to the edge of the forest, the distance to the clear-cut area, the distance to the drainage system and the distance to the road. It was found the distance from the forest edge had a significant effect ($r = 0.39$, $p < 0.05$) (Fig. 7), as well as the distance to the drainage system ($r = 0.24$, $p < 0.05$) (Fig. 8) and the distance to the road ($r = 0.25$, $p < 0.05$) (Fig. 9). No significant effect of the distance to the clear-cut area on the amount of deadwood was found ($r = -0.06$, $p > 0.05$). When looking further into the role of the forest‘s edge location, it was discovered that he smallest amount of deadwood was found when the distance to it was under 20m (average of 9 units per plot), while the biggest amount was found at 500m from the edge of the forest (average of 20 units per plot). Similar trends could be observed when in the analysis of distance to the drainage system and the road. The smallest amount of deadwood was found when the distance was under 50m to the drainage system or the road (average of 11 units per plot) and the largest when the distance was under 200m to them (average of 18 units per plot). Forest management activity, such as sanitary felling, had the greatest impact on this distribution of deadwood quantities, likely because cutting down trees with the smallest distance to the edge of the forest or road, where the drainage system is usually located, is the only way sanitary tree cuts can be economically beneficial. Deadwood is also removed from the locations near the roads, drainage systems and the edges of the forests due to health and safety risks of people living, visiting or working there and their property.

The distribution of all deadwood and the presence of deadwood in forests with hardwood deciduous, softwood deciduous and coniferous species of tree prevalence were separately analysed when analysing deadwood distribution by stage of decomposition's dependency on the predominant species of tree. Upon looking at the overall volume of deadwood, it was found that the most common wood was at its third stage of decomposition (average of 5.9 units per plot), while the least amount of wood was at its fifth stage (average of 0.8 units per plot) (Fig. 10). The largest part of all deadwood was at the second to fourth stage (average of 13.1 units per plot). This has positive importance for the conservation of biodiversity as the epiphytic species often found on the first stage deadwood can be found on green standing trees as well. Epixylic species take hold only during the latter stages of deadwood, while epigeic species may

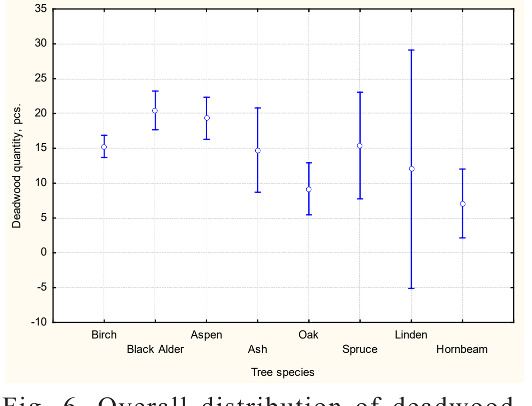


Fig. 6. Overall distribution of deadwood depending on the tree species.

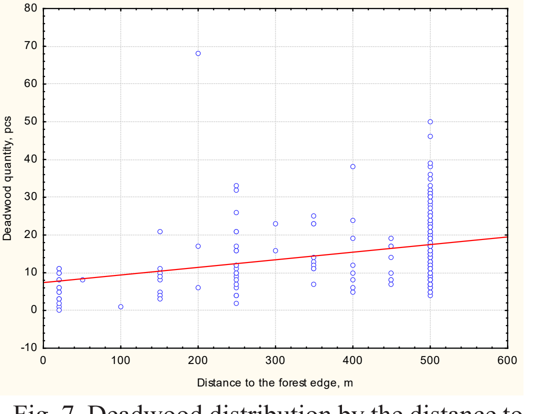


Fig. 7. Deadwood distribution by the distance to the forest edge.

start growing when the deadwood gets covered in soil. Wood at its second to fourth stages of decomposition holds positive implications for the abundance of organisms that are related to deadwood. The largest ammount of second stage deadwood was discovered in woods with the prevelance of the common spruce *(Picea abies)* and black alder *(Alnus glutinosa)*, at the average of 9 units per plot, and the least – with prevelance of common hornbeam *(Carpinus betulus)*, at the average of 2.5 units per plot. A slightly larger amount of deadwood at its first stage was found only in woods with the prevelance of common ash *(Fraxinus excelsior)* and littleleaf linden *(Tilia cordata)*, average of 5 units and 4 units per plot respectively. An average of 1.9 unit per plot of first stage deadwood was found in every tree species of wood, which was still less than the amount second to fourth stage wood found. These findings have a negative significance on preservation of biodiversity as first stage wood is important not only to species that are related to deadwood but also to the continuous presence of deadwood itself. The use of timber for economic purposes has the biggest impact on the reason why the number of first stage of deadwood is so small. On evaluation of the distribution of deadwood among hardwood deciduous, it was discovered that most of it is acummulated in woods where common ash *(Fraxinus excelsior)* is prevelant (average of 3.1 unit per plot), while the distribution among softwood deciduous is the most largest with black alder *(Alnus glutinosa)* predominant (average of 7.5 units per plot). It

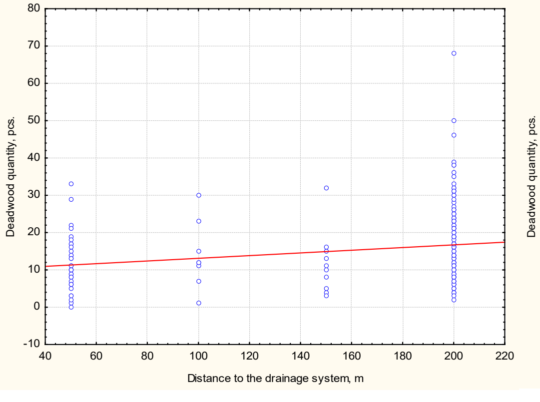


Fig. 8. Deadwood distribution by the distance to the drainage system.

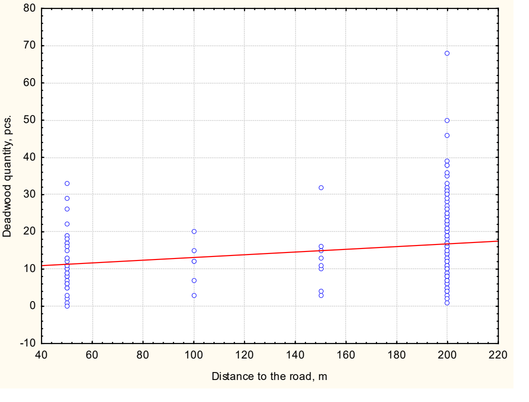


Fig. 9. Deadwood distribution by the distance to the road.

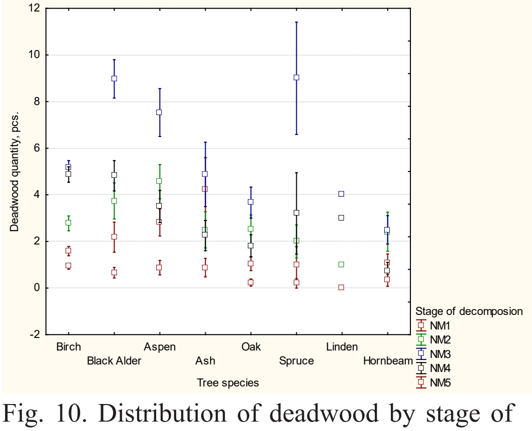


Fig. 10. Distribution of deadwood by stage of decomposion and tree species.

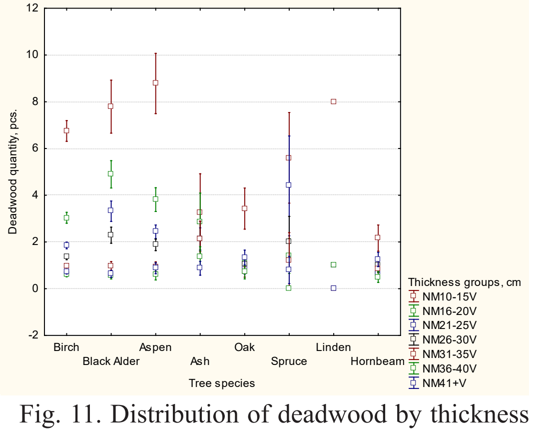


Fig. 11. Distribution of deadwood by thickness groups and tree species.

was also determined that the most common type of deadwood was softwood deciduous – average of 9 units per plot.

When analysing the distribution of deadwood by groups of thickness dependency on the tree species, the distribution of all deadwood was analysed on its own in addition to hardwood deciduous, softwood deciduous and coniferous deadwood saparate analyses. Upon measuring the total amount of dead it was discovered most of the deadwood had 10-15cm diameter (average of 6.5 units per plot), while least had 36-40cm diameter (average of 0.6 units per plot) (Fig. 11). Most of 10-15cm diameter timber was seen in woods with prevelance of aspen (*Populus termula*) – average of 8.5 units per plot; 16-20cm diameter in woods with prevelance of black alder (*Alnus glutinosa*) – average of 4.9 units per plot; 21-25cm diameter in woods with prevelance of common spruce (*Picea abies*) – average of 4.5 units per plot; 26-30cm diameter in woods with prevelance of black alder (*Alnus glutinosa*) – average of 2.3 units per plot; 31-35cm diameter in woods with prevelance of common ash (*Fraxinus excelsior*) - average of 2.1 unit per plot; 36-40cm diameter in woods with prevelance of common ash (*Fraxinus excelsior*) - average of 1.3 unit per plot; 41cm or larger diameter in woods with prevelance of common oak (*Quercus robur*) - average of 1.5 unit per plot. Small deadwood prevailed in softwood deciduous stands, while large deadwood could be mostly found in hardwood deciduous stands. Upon saparate analysis on hardwood deciduous, softwood deciduous and coniferous deadwood distribution by thickness groups, it was found that small deadwood is not always prevelant. The significance of small deadwood on biodiversity is relatively small, as it consists of thin, young and quickly decomposing wood. Sadly, there is a lack of large deadwood, which makes sure of long-term presence of deadwood and is important to most organisms related to deadwood.

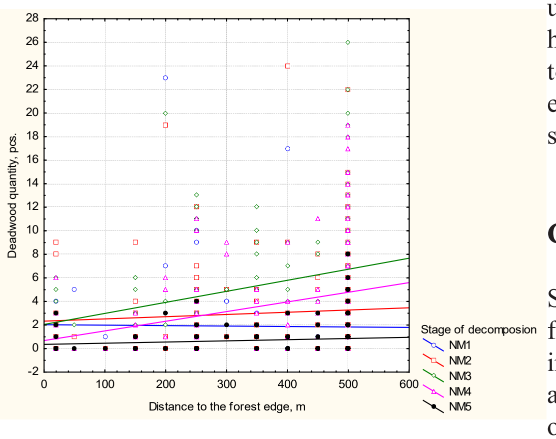


Fig. 12. Distribution of deadwood by stage of decomposion and the distance to the forest edge.

After analysing the distribution of deadwood by its state of decomposion and forest groups, as well as by thickness group and forest group analysis, it was established that third stage of decomposion and small deadwood was the most prevelant, regardless of the group of the forest.

Finally, the distribution of deadwood by its state of decay depending on the distance from the forest edge was analysed.

The results indicate a reliable influence of distance to forest edge on deadwood in its third ($r = 0.37$, $p < 0.05$) and fourth ($r = 0.37$, $p < 0.05$) stages (Fig. 12.). The longer was the distance to the forest edge, the more deadwood could be found. The smallest amount of deadwood could be found at 20m or less to the edge of the forest and the largest amount at 500m to the edge of the forest. As the distance increased, the amount of third stage deadwood per plot increased from 2 units to 7.7 units. Once again, forestry activities had the biggest influence on this disposition due to sanitary fellings being more economically efficient when the distance to the forest edge is smaller.

CONCLUSIONS

Site humidity has a significant influence on the formation of deadwood. As the humidity of soil increases, the trees' resistance to negative abiotic and biotic factors decreases, as well as the amount of deadwood increases.

Site types (site humidity with site fertility) has a significant impact on the amount of deadwood present. As the soil's humidity and fertility increases, so does the presence of deadwood.

The dominant tree species has a huge impact on the amount of deadwood. The largest amount of deadwood is formed in areas dominated by softwood deciduous, smallest – by hardwood deciduous trees.

The amount of deadwood increases with the distance from the forest edge, drainage system and road increases. This distribution is determined by forestry, as sanitary fellings are economically useful only when the distance from a edge of the forest or a road, where drainage system is usually located, is small.

Most of the deadwood consists of second to fourth stage of decomposion wood, the abundance of which has positive influence on the wealth of organisms related to deadwood.

Large amounts of small deadwood which has little impact on biodiversity was found, while there is a lack of large deadwood which ensure long-term presence of deadwood and is important to organisms related to it.

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