Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XII, 2023
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE IMPACT OF LOGGING ACTIVITY ON RESIDUAL TREES - A CASE STUDY FROM SOUTHWEST ROMANIA

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Abstract

The paper aims to analyze the impact of logging activity on residual trees from logging yards from southwest Romania, located in plain, hill and mountain area and covered with a large variety of silvicultural works-first-intervention cuttings, preparatory and seed-cutting (shelterwood systems or selection systems), cuttings to increase light availability for regeneration (shelterwood systems), final cuttings (shelterwood systems). The impact of logging activity on the residual trees was analyzed based on the data obtained from the measurements made at the end of the vegetation season of 2019 and the beginning of the vegetation season of 2020. Based on the data obtained, the total number of tree damages in the variants studied on relief forms, the relationship between the number of tree damages and different stand characteristics, and the damages distribution by their types in the studied variants, were analyzed. Trees damage evaluation was done by determining damage indexes calculated as a ratio between the volume of damages found and the volume of damaged trees. The most important conclusions have been discussed in the context of other researches in the field.

***Key words**: tree damage, logging yard, barking wound, trees wound.*

INTRODUCTION

Logging technologies must be correlated with treatments that are adequate to the essential characteristics of stands in order to preserve the protection potential of forests. This correlation is mandatory for harvesting wood material as well as for fulfilling the necessary conditions for natural regeneration and for creating healthy and valuable economically stands (Dămăceanu & Gava, 1991). Logging works leads to soil compaction and damage to saplings and trees (Whitman et al., 1997). Soil compaction caused by logging machines has an important influence on seedling growth and/or mortality (Picchio et al., 2019).

Logging damage to residual trees is one of the potential difficulties of logging works in any stand (Clatterbuck, 2006). In this process, when harvested trees are moved and the residual stand is dense, damage to residual trees are inevitable (Picchio et al., 2012). In order to remove harvested timber from the stand, repeated entries of machines in the stand are necessary, but this activity increase the risk of damages to residual trees (Ficklin et al., 1997).

However, in terms of serious injury, feeling of trees are the major source of this type of damages (Fairweather, 1991). Stand damages from this category can be reduced by a prior planning of felling direction (Tavankar et al., 2013). Frequency of felling damage is increasing with the level of timber removals and skidding damage is higher when the number of trees in adjacent area of skid trails is high (Hartsough, 2003).

Regarding damages resulting from timber transportation from harvesting place to the loading point, most of them are within the root collar and in the lower part of tree trunk (Cudzik et al., 2017).

The technique of timber harvesting can result to important damages to residual trees and seedlings, and also to timber products and soil, but the logging damages can be minimized by using a proper technique for harvesting (Eroğlu et al., 2009). For a feasible harvesting system, the machinery used in logging should be chosen based on their impact on ecosystem, not only based on productivity rate (Akay et al., 2006).

The paper aims is to analyze the impact of logging works on residual trees on logging yards where different silvicultural works were applied and to assess tree damages on considered variants.

MATERIALS AND METHODS

The studied logging yards were chosen in different relief areas to reduce the influence of the geomorphological and vegetation conditions and at different managers of the forest fund, to reduce the influences given by the logging technology, the machine system available to a certain agent in the respective area, the mode and working habits of the logging teams. The layout of research in variants and logging yards is presented as follows:

- Variant V1 - logging yards where thinning works were applied from the plains (OS (Forest departmant) Bocşa Română - UP (production unit) II, u.a. (management unit) 58A and UP III, u.a. 49), hill (OS Bocşa montană - UP VI, u.a. 95A and OS Moldova Nouă - UP III, u.a. 15B) and mountain (OS Băile Herculane - UP II, u.a. 23 and BE (Experimental base) Caransebeş - UP VI, u.a. 99A);
- Variant V2 - logging yards with first-intervention cuttings, preparatory and seed-cutting within shelterwood systems or selection systems, from the plain (OS Bocşa Română - UP I, u.a. 11C and UP II, u.a. 55), hill (OS Bocşa Montană - UP IV, u.a. 62B and OS Moldova Nouă - UP III, u.a. 212A) and mountain (OS Văliug - UP VI, u.a. 15A and u.a. 16A);
- Variant V3 - logging yards where cuttings to increase light availability for regeneration where applied within shelterwood system at the plain (OS Bocşa Română - UP III, u.a. 28B and 76A), hill (BE Caransebeş - UP II, u.a. 30B and OS Moldova Nouă - UP III, u.a. 176A) and mountain (OS Băile Herculane - UP II - u.a. 99A and 100A);
- Varianta V4 - logging yards where final cutting within shelterwood system were applied at plain (OS Bocşa Română - UPI, u.a. 1E şi 14A), hill (BE Caransebeş - UP I, u.a 46D şi OS Moldova Nouă - UP III, u.a. 162B) and mountain (OS Băile Herculane – UP IV, u.a. 98A and BE Caransebeş – UP V, u.a. 16A).

Along the collection paths, in each logging yard, the research was carried out in three sample areas of a 100 m long section along the most representative collection path, arranged in the upstream part, in the middle and respectively in its downstream part (Figure 1). Inside each logging yard, the research was carried out in the initially installed surfaces, namely for each parquet, in a circular sample area of 2500 m^2 located in the middle area of the logging yard in such a way that it does not include areas of collection paths.

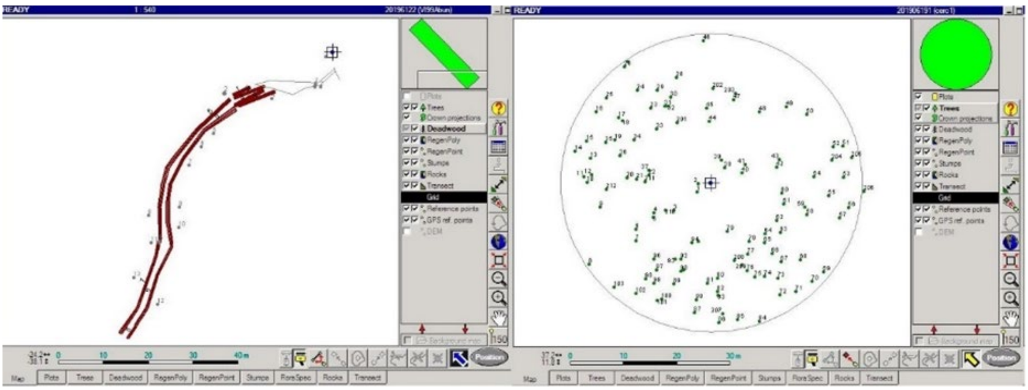

Figure 1. The location of the sample areas (along the collection trails - left, inside the logging yard - right) (FieldMap System)

The impact of logging works on the residual trees was analysed based on the data obtained from the measurements made at the end of the vegetation season of 2019 (in logging yards from mountain area) and the beginning of the vegetation season of 2020 (in logging yards from plain and hill area) in the previously presented sample areas.

The carried out field work followed: identification of the tree, observation of the status of the tree (dead/alive), identification of each damage previously found based on its type (galling (bark removed partially without cambial lesions.) barking (areas with bark removed up to the wood), splintering (areas with bark and wood removed), breaking (the trunk or the branches), uprooting (total or partial), according to Knežević et al. (2018)).

Based on the data obtained, the total number of tree damages in the studied variants on relief, the relationship between the number of tree damages and the different characteristics of the stand, as well as the distribution of damages by their types in the variants studied, were analysed.

The evaluation of wound and damages caused to trees through logging works was done by determining damages indexes calculated as a ratio between the volume of damage found and the volume of damaged trees. Tree damage indexes were determined for each type of damage, for total trees and for each variant separately, based on the relationship 1:

$$i = \frac{V_v}{V_{av} \times 1000} \quad (1)$$

where:

i - damage index;

V_v - damage volume (cm^3);

V_{av} - damaged tree volume (m^3).

In the formula 1, the volume of the damages was determined based on their dimensional characteristics as the product of the length, width, and depth of each damage. In order to determine the damage indexes, it was necessary to relate the volume of damages at the volume of damaged trees. The latter was calculated using formula 2 (Giurgiu et al., 2004):

$$\log V = a_0 + a_1 \log d + a_2 \log^2 d + a_3 \log h + a_4 \log^2 h \quad (2)$$

where:

a_0, a_1, a_2, a_3, a_4 - the values of the regression coefficients on species;

d - tree diameter (dbh) (cm);

h - tree height (m);

V - tree volume (m^3).

RESULTS AND DISCUSSIONS

Results regarding the impact of logging activity on trees

A total number of 1,237 damaged trees were identified in all the sample areas of the logging yards, distributed as follows: 537 trees in the V1 variant, 254 trees in the V2 variant, 215 trees in the V3 variant, 231 trees in the V4 variant. Regarding the type of damages compared to their total number, 1945 damages were identified - many trees have multiple damages - most of them being barking (78.9%), followed in descending order by splintering (11%), galling (7.7%), broken trees (1.8%) and uprooting in a very small percentage (0.6%).

Analyzing the total number of damages in the studied variants by categories of relief, the most damages were recorded in the hills and mountains in all the variants, with a maximum of them in variant V1 - Thinning (Figure 2). In the plain, the fewest damages were found in all the variants. Here, relief energy plays an important role in producing damages to trees.

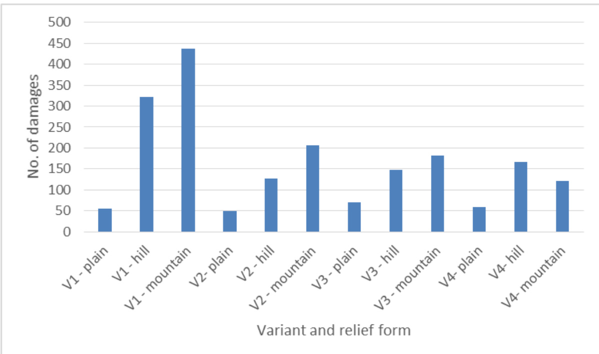

Figure 2. The total number of tree damages in the studied variants, on relief forms

There is a proportional relationship between the total number of damages identified for each logging yard and certain logging yard or stand characteristics (Figure 3).

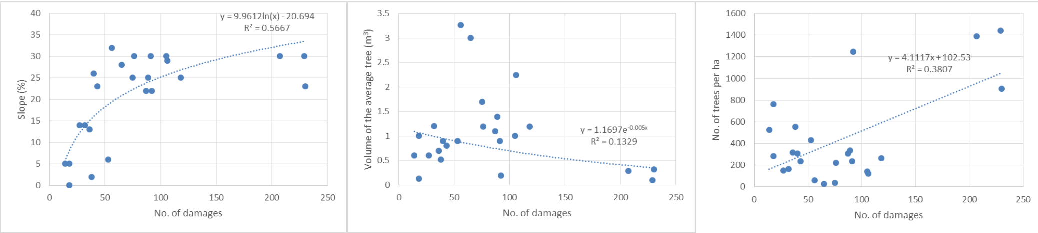

Figure 3. The relationship between the number of tree damages and different stand characteristics: (a) - the relationship between the total number of damages and the slope; (b) - the relationship between the total number of damages and the volume of the average tree; (c) - the relationship between the total number of damages and the number of trees per ha

The slope in the logging yards directly proportionally influences tree damages number (Figure 3a). The increase in the damages number with the increase of the slope is logarithmic, the slope in the logging yards leading to a higher number of damages. The slope makes it difficult to gather and caring the wood material, it changes the trajectory of the loads, inevitably leading to damage to the trees.
Large values of the volume of the average logged tree led to a lower number of damages (Figure 3b), registering an exponential increase in the number of damages with the decrease in the volume of the average tree. At high values of volumes of the average logged tree, the number of loads is lower and including machine passes, skidder tractors are lower. At low volumes, the loads are more, requiring more runs to collect, thus resulting in a higher number of damages.
The number of trees per hectare influences directly and proportionally the number of damages (Figure 3c). A large density of the stands makes it difficult to collect and remove the wood material, inevitably leading to damage to the trees.
As previously analyzed, the negative impact of logging activity on trees is related to the slope of the land, the average tree volume and the number of trees per ha. By analyzing the number of damages for each variant separately, it is observed that the most damages, both in terms of their types and in total number, are those in variant V1 - Thinning (Figure 4), where the number of trees is the highest, this being decisive for the occurrence of damages.

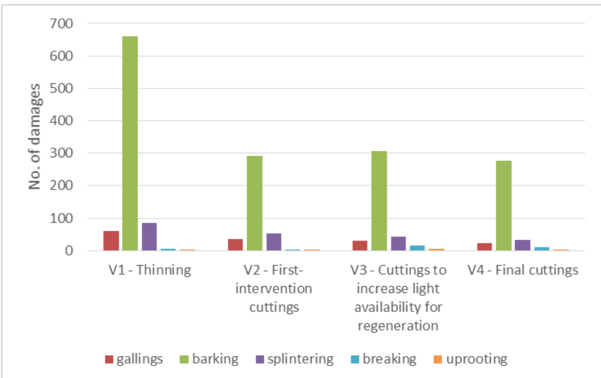

Figure 4. The distribution of damages by their types in the studied variants

The most frequently identified damage, barking (78.9% of the total number of damages) (Figure 4), shows the same trend as the total number of damages, influencing it directly. The number of

barking and also damages of other types, found in thinning, is much higher than that of the other variants, the dynamics of their production being influenced by the same variables that influence the production of all damages, mentioned and discussed previously.
As for the galling, it can be seen (Figure 4) that they are relatively evenly distributed in the studied logging yards with a slight increase in the thinning where the most damages are recorded.
Splintering register an almost identical trend to barking, and more serious damages (breaking, uprooting) are found in all the studied variants studied and in most of the logging yards.
The fewest braking and uprooting were observed in variant V2 - First intervention cuttings, and the most in variant V3 - Cuttings to increase light availability for regeneration, where the extracted volumes are larger and the remaining trees are still in significant numbers compared to the variant V4 - Final cuttings.

Assessment of tree damages
The method used to assess the impact of logging activities on the trees, is based on damage indexes, by damage types and total damages, calculated as a ratio between the volume of each tree damages and the volume of injured trees based on the formula presented in the material and method chapter. Considering that the number of broken or uprooted trees is very small and that most of them were extracted from the logging yard, their diameter and height not being able to be measured, the calculations below refer only to galling, barking and splintering. Tree damage indexes were calculated for each damage type, for total trees and for each logging yard. Damage indexes thus calculated, are shown in Table 1.

Table 1. Indexes of tree damage by types of damage in the studied variants

Variant	Relief form	Damage index			
		Galling	Barking	Splintering	Total
V1 - Thinning	Plain	0.490	0.726	0.720	0.708
	Hill	1.630	2.191	5.509	2.235
	Mountain	0.035	1.318	0.889	1.218
Total V1		1.289	1.619	1.528	1.585
V2 - First intervention cuttings	Plain	0	18.327	45.370	20.535
	Hill	0.0396	22.778	29.795	19.199
	Mountain	0.019	1.894	4.419	2.217
Total V2		0.033	10.863	13.913	10.255
V3 - Cuttings to increase light availability for regeneration	Plain	0.0006	10.972	12.297	10.987
	Hill	0.0278	17.962	0.089	14.504
	Mountain	0.011	0.837	1.440	0.843
Total V3		0.019	9.080	3.380	7.711
V4 - Final cuttings	Plain	0.011	28.378	15.775	26.222
	Hill	0.0771	28.101	20.096	24.272
	Mountain	0.024	3.196	5.860	3.289
Total V4		0.058	19.038	15.528	17.317
TOTAL		0.533	8.006	7.125	7.313

As can be seen in Figure 5a and in Table 1, galling has the highest values of the damage index in the logging yards from the plain where thinning works were applied. In this variant, the impact of logging is minimal, galling being the lightest damage produced by logging activities. In these logging yards where thinning works were applied, the loads formed by trees with small volumes, light but with little potential for damages, led to a large number of damages in this category.
The barking has the highest values of the damage index in logging yards where final cuttings were applied, where residual trees

were subjected to the impact of loggings works during relatively recent previous works (Figure 5b).

Splintering dislodges the largest volumes of wood at the level of the damages, compared to the volume of the trees, in the logging yards from the V2 variant where first intervention cuttings were applied (Figure 5c). Here, the exploited volumes are significant, and the number of trees during the cutting for opening the regeneration areas is still high.

Analyzing the damage index for all damages in the studied variants (Figure 5d), high values are observed in the case of variant V4 - Final cuttings, for all three types of analyzed damages. This a fact is determined by the small number of trees remaining in the logging yard, or that have reached the necessary diameter to be included in the research, most of them collecting damages from all the cuts within the shelterwood system, that have taken place in the last period.

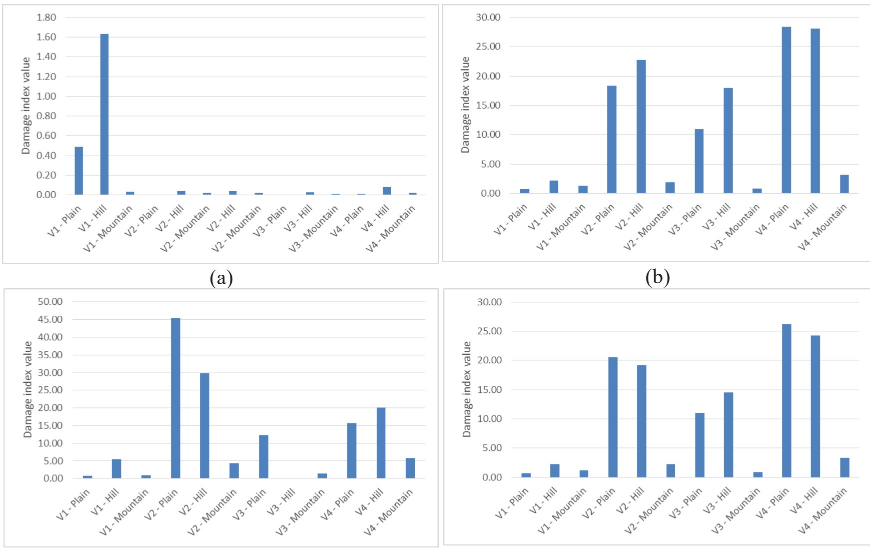

Figure 5. Damage indexes for trees by types of damage (a - galling; b - barking; c - splintering; d - total damages)

CONCLUSIONS

Barking is the most common damage identified in the repetitions from the studied versions (78.9% of the total number of damages), followed by splintering (11%) and galling (7.7%). Ruptured and uprooted trees are present only in a very small percentage. Results from similar studies that were focused however on animal logging, have also placed barking on the first place (61.5%), followed by light damages such as squashed bark (23.1%) and small percentages for debarked and damaged tree (15.4%). Unlike our study, the higher percentage of light damages is caused by using animal logging, an exploitation technology from the reduced impact logging category (Knežević et al., 2018). Other studies have shown that, on average, logging damage affected 40% of residual trees, with 21% being injured and 19% being dead trees (Bertault & Sist, 1997).

The most damages were recorded in the hills and mountains in all the variants, with a maximum of them in variant V1 - Thinnings. As for subsequent growths for trees damaged through logging in thinning, Norway spruce forests from nordic countries was applied the whole-tree harvesting process that has caused a significant decrease in volume growth, especially in the following 10 years (Helmisaari, 2011). Even though trees in logging yards where thinning were applied are young, some authors mentioned that the cambial tissue never survives exposure. In this way, even if some small bark pieces are removed, the xylem is open to an invasion of pathogen agents. Closing bark lesions varies on the quantity of removed bark, as well as on the vigor and the species, while all damaged trees will maintain rot pockets even after minor damages and regardless of age. Heavier damages will result in the following decades inside the stem's interior rot (Putz et al., 2008).

In order to protect the forest ecosystem, some studies show that applying specific measures can reduce with 25-33% the damages on residual trees (Johns et al., 1996). These measures must be feasible from a technical perspective and acceptable from an economic one (Jonkers, 2000).

The fewest damages found in all the variants from the plain, lead to conclusion that the relief energy plays an important role in producing damages to trees. The slope in the logging yards directly proportionally influences tree damages number. Large values of the volume of the average logged tree lead to a lower number of damages. The number of trees per hectare influences directly and proportionally the number of damages. Similar results were found in other studies, showing that residual tree damage level is correlated to terrain slope, density of stand and logging intensity (Tavankar et al., 2015).

The barking have the highest values of the damage index in logging yards where final cuttings were applied and splintering dislodge the largest volumes of wood at the level of the damages, compared to the volume of the trees, in logging yards where first intervention cuttings were applied.

ACKNOWLEDGEMENTS

This paper was carried out with the support of the Ministry of Research, Innovation and Digitization (MCID), through "Programul 1 - Dezvoltarea sistemului naţional de cercetare - dezvoltare, Subprogram 1.2 - Performanţă instituţională - Proiecte de finanţare a excelenţei în CDI" - project "Creșterea capacității și performanței instituționale a INCDS „Marin Drăcea") în activitatea de CDI - CresPerfInst" (Contract no. 34PFE./30.12.2021) and Nucleu BIOSERV Programme (Ctr. 12N/2019), project PN19070507. The paper was carried out also, with the support of National Institute for Research and Development for Forestry "Marin Drăcea" through the Program of Research in own Bases – project P1/2022.

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