

RESEARCH OF MECHANICAL DAMAGE ON FIR TREES AND OTHER TREE SPECIES DURING EXPLOITATION – CASE FORESTRY “GLAMOČ”

ISTRAŽIVANJE MEHANIČKIH OŠTEĆENJA STABALA JELE I DRUGIH VRSTA TIJEKOM EKSPLOATACIJE – SLUČAJ ŠUMARIJE „GLAMOČ”

Velid HALILOVIĆ¹, Jusuf MUSIĆ¹, Jelena KNEŽEVIĆ¹, Mario ŠARIĆ², Besim BALIĆ¹, Dalibor BALLIAN¹

SUMMARY

Mechanisation used in forest utilisation has an impact on the occurrence of damage in stand and on forest land. The research in this work had the objective of determining damage on fir trees and other tree species during felling and processing of trees and their skidding using the forest cable-skidder. The research was conducted in mixed beech and fir forests in the area of FMA “Glamočko”, M.U. “Hrbinje-Kujača”. The following data were gathered on damaged trees: tree type, breast height diameter, economic importance of the tree, amount of damage, location of damage, cause of damage, types of damage. Damage was recorded on a total of 305 trees, 133 trees of silver fir (*Abies alba*), 130 trees of European beech (*Fagus sylvatica*), 33 trees of European spruce (*Picea abies*), 8 trees of rowan/mountain-ash (*Sorbus aucuparia*) and one tree of sycamore (*Acer pseudoplatanus*). The overall damage intensity was 18.7%, but together with the old damages, the overall number of ‘wounds’ is 496. According to this, when the old damage is also considered, then the intensity of damage amounts to 30.6%. The largest amount of damage is in the diameter sub-class ranging from 10 to 14.99 cm. According to the cause of damage, the largest amount of damage occurred during the wood extraction phase (217 trees), while during the felling phase, 88 trees or 29% were damaged. Since the wood extraction phase is divided into the winching and skidding phases, the total number of damaged trees during the winching phase amounted to 157 or 52%, while during the skidding phase, the number of damaged trees was 60 or 19%. To reduce damage to the trees during following operations in forest utilisation, it is necessary to perform more frequent training of all employees working on forest utilisation, to increase controls in execution of operations during forest utilisation, modernise machines used during forest exploitation, and in quality manner open compartments with forest road infrastructure.

KEY WORDS: fir, trees, felling, wood extraction, damage.

INTRODUCTION

UVOD

One of the objectives of forest utilisation is the participation in the management of forest resources that will ensure the processing of the most valuable assortments with min-

imum production costs; and will increase work efficiency and with that humanise the work and cause the least damage to the environment (Kulušić 1977). During the forest utilisation process, damage in the stand appears, which unfortunately cannot be avoided but has to be brought down to tolerable level (Kulušić 1990). Under damage we include

¹ Prof. dr. Velid Halilović, e-mail: v.halilovic@sfsa.unsa.ba; prof. dr. Jusuf Musić, e-mail: j.music@sfsa.unsa.ba; mr. Jelena Knežević, e-mail: j.knezevic@sfsa.unsa.ba; prof. dr. Besim Balić, b.balic@sfsa.unsa.ba; prof. dr. Dalibor Ballian, d.ballian@sfsa.unsa.ba; Faculty of Forestry, University of Sarajevo; Zagrebačka 20, 71000 Sarajevo

² Mr. Mario Šarić, e-mail: saricmario028@gmail.com; Forest-Management Company “Hercegbosanskešume” ltd Kupres; Splitska bb, 80320 Kupres

damage on the stem, seedling, young growth and forest land and pollution of water during forest operations with consequences that are shown in the reduction of beneficial forest functions (Petreš 2006).

Various factors have an impact on the damage of the stand during forest operations, and the most important ones are: characteristics of the terrain and stand, types and characteristics of technical means, technology and work method and man's attitude toward the work.

Mechanisation which is ever more frequently used in the technological process of forest utilisation impacts larger effectiveness during utilisation. However, due to the use of mechanisation, there has been a significant increase in damage occurring in the stand and on forest land. Damage on standing trees in the stand most often appears in the felling and wood extraction phases. During the felling phase, damage occurs on surrounding trees mainly on their crown and in form of crushing of tree bark which is confirmed in the research by Danilović et al. (2015).

During the skidding phase, great damage appears that has the toughest consequences on the rest of the stand. In this phase of the extraction of wood assortments by tractors, the wood mass gets stuck to standing trees which caused bark to peel off and leaves a possibility of penetration of pathogens. This is confirmed in the research by Vasiliauskas (2001).

Stem and butt end damage is economically the most harmful because mainly the most valuable part of the stem is damaged. This was confirmed in the research by Behjou (2016).

Examination of damage, that appears during the felling and processing, extraction and transport phases of wood mass, was dealt with by many researchers (Kaminsky 1984; Dvorak and Iordache 2010; Badraghi et al. 2015).

Damage that occurs on trees is largely caused by density of roads, i.e. the distribution of the primary and secondary road network (Ostrowsky 1988).

Damage to trees of fir and other species during the skidding phase using the Timberjack 240C skidder in variable aged stands of Gorski kotar was researched by Sabo (2003). According to this author, a series of indicators on damage and wounds to the stand confirm the assumption that stand and terrain conditions are determining factors of damage, with equal other conditions – technology and methods, work assets and work executioners.

Martinić (1991) determined, through the analysis of damage in the stand of beech, sessile oak and oriental hornbeam, that the largest amount of damage occurs during extraction of wood mass (53%), and regarding the place of damage, most damage appears on the root collar.

Damage on tree parts was researched by Tavankar (2013), who determined that most of the damage appears on a height of up to one meter. According to the same author, a larger amount of damage appears during the extraction of wood mass (5.2–11.1%) compared to felling (1.4–3.4%).

Solgi and Najefi (2007) determined that the largest amount of damage, during forest utilisation using skidders occurs on the root (41%) in beech and hornbeam forests in Iran.

During felling, crowns of neighbouring trees are mostly damaged, while during skidding of wood mass, the root system is mostly damaged. Also, during the same research it was determined that the most common width of the damage ranges from 50 to 200 cm² (Danilović et al. 2015).

According to research by Hartsough (2003), the largest amount of damage is in the lower diameter sub-class, confirmed by Zahirović et al. (2016).

According to the research by Zahirović et al. (2016), in forests of fir and spruce it was determined that trees with one damage each appear the most. It has also been determined that spruce has more damage to roots and stem compared to the crown, while in the case of fir it is vice-versa. Based on the same research, authors reached the data that say that most damage appeared on the stem (71.6%), while crown had 18.8% and root collar had 9.6%. Mentioned by the same author, in forest of fir and spruce it is determined that average size of damage on fir was 607.14 cm², and on spruce was 407.27 cm² during felling with chainsaw and extraction of wood mass using a skidder.

Damage on trees most favourably affected the occurrence of disease on those trees and represent the biggest danger to the surrounding healthy trees (Vasiliauskas 2001).

Akayet et al. (2004) propose to synchronise felling with characteristics of forest, type of mechanisation and intensity of felling, including some other factors that affect the effectiveness of work.

Erogluet et al. (2009) state that technique and technology of work have to be focused on the reduction of damage to the remaining trees, young growth and land/soil.

During mechanised skidding of wood assortments, in addition to stand damage (standing trees and young trees) there is also damage to the environment (soil, water, discharge of pollutants, etc.). This and similar research represented the subject of study for numerous authors (Calcante et al. 2018; Ilintsev et al. 2018; Karaszewski et al. 2018; Marusiak and Neruda 2018; Solgi et al. 2018; Labelle and Lemmer 2019; Solgi et al. 2019a; Solgi et al. 2019b.).

Problems that appear during forest utilisation are present in Bosnia and Herzegovina. Wood extraction by animals is less and less present, unlike extraction by cable-skidder with

ever growing presence. Good work organisation and larger attention of those performing forest utilisation operations should impact the reduction of damage on trees (Halilović et al. 2019).

The objective of the research is to determine various indicators of damage to standing trees during the felling and wood extraction phases of fir and other species of wood in fir – beech uneven aged stands in the area of Forestry Glamoč. Indicators of damage will present themselves with the following features of damaged trees: tree type, breast height diameters of damaged trees, cause of damage, size of bark damage, place of damage, management significance of damaged tree and status of damaged trees.

MATERIAL AND METHODS

MATERIJAL I METODE

The research was done in the area managed by C.F.M.C.³ “Hercegbosanske šume” ltd Kupresin the area of F.M.A. “Glamočko”. F.M.A. “Glamočko” consists of five management units; M.U. “Hrbinje-Kujača” was selected for research. Inside this management unit we selected compartment 174 and sub-compartment b (figure 1). Compartment 174/bis located at an altitude between 1300 - 1400 meters. The surface of this compartment is 54.91 ha.

Sub-compartment “b” belongs to the management class 1211 – “Forests of beech and fir with spruce on primarily deep calcocambisol, luvisol and their combinations on firm limestone and dolomite”. The ratio of mix per wood growing stock in compartment is the following: fir 42.87%, beech 41.63% and spruce 13.71%. Out of other tree species, 1.30% are valuable broad-leaved species and 0.49% of soft broad-leaved species. Wood growing stock is 260.35 m³/ha and total growing stock is 14,295.82 m³. Fir has a total growing stock of 6,128.04 m³ (110.60 m³/ha), spruce 1,960.42 m³ (35.70 m³/ha), beech 5,952.98 m³ (108.40 m³/ha), valuable broad-leaved species 185.56 m³ (3.38 m³/ha) and soft broad-leaved species 69.80 m³ (1.27 m³/ha).

A road, 2.2 km in length, passes through this compartment and also along the part of the border of the compartment there is a road of 3.5 km in length. The total length of all skidding trails in compartments is 5.2 km. Therefore, the openness of compartment is 10.37 m/ha. The average skidding distance is 501-750 meters. Terrain conditions are moderately favourable for work. For the most part of the terrain, there are no significant slopes. Slopes are mainly in average of about 25%.

Tree felling and extraction of cut wood mass was done in May 2018, with the total cut of approx. 2,900 m³, and out

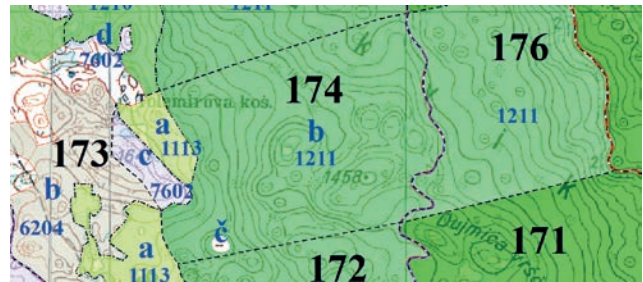


Figure 1 M.U. “Hrbinje-Kujača”, compartment/sub-compartment 174/b
Slika 1. G.J. „Hrbinje-Kujača”, odjel/odsjek 174/b

of that number 1,550 m³ are conifers and 1,350 m³ are broad-leaved species. Total marked trees are 2,008, and average marked volume of trees is 53.16 m³/ha. The achieved intensity of marking of 16.52% for conifers, 20.72% for broad-leaved intensity, and total intensity is 18.30%. The intensity was adjusted to the conditions of the stand, i.e. the achieved intensity is larger than prescribed, due to the damage from previous work period and bad quality of beech trees.

The phase of felling and processing was done by two groups in formation 1+1 (one cutter and one assistant worker), and the felling was conducted using the chainsaw by the manufacturer STIHL model MS 362 (figure 2). The extraction of cut wood mass was done using three LKT 81



Figure 2 Stihl chainsaw
Slika 2. Motorna pila Stihl



Figure 3 LKT81 Skidder (foto: Šarić M.)
Slika 3. Traktor LKT81

³ Cantonal Forest Management Company

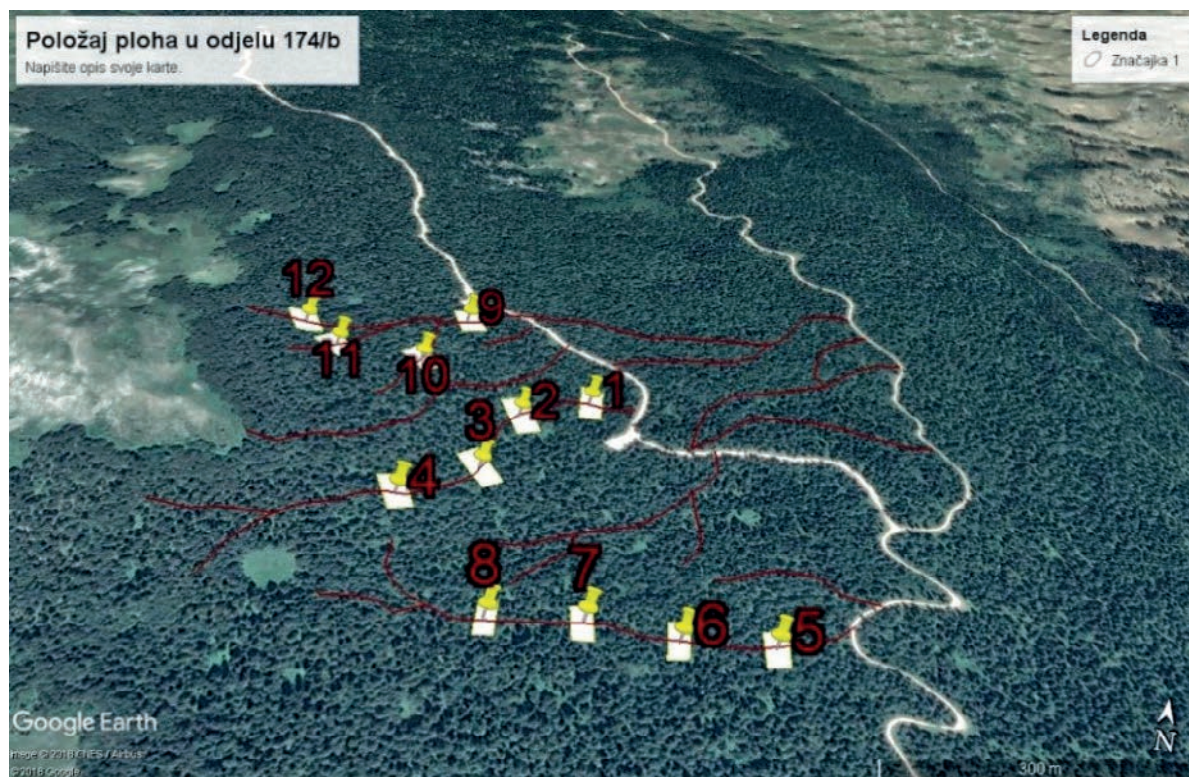


Figure 4 Sample plots' position in compartment/sub-compartment 174/b (Google Earth Pro⁴)

Slika 4. Položaj pokusnih ploha u odjelu/odsjeku 174/b

skidders (figure 3). The applied work method was assortment work method.

Prior to the initiation of all operations in M.U. "Hrbinje-Kujača", we set-up plots in compartment 174/b. 12 plots were set. Dimensions of the plots were 30x30 meters.

The plots were set using compasses, by determining the azimuth from the skidder trail and then measuring using measuring tape 30 meters into the length of the plot. Borders of the plots were marked with spray by marking border trees. Trees were marked with two red lines and a point between them. In such a manner, the number of the plot and the mark of the zone were written.

In defining the plot site, we used the program Google Earth Pro (figure 4). Microsoft Excel was used for data processing. Also, other tools were used such as a compass, measuring tape, calliper, ruler and GPS.

In determining the damage per damage location, we applied the classification determined by Meng (1978), which separates four categories of damage: damage to the root, damage to root collar, damage to butt end and damage to stem.

Also, damage that had appeared in the past work period was recorded, which was then characterised as "old damage". We analysed exclusively trees above the taxation

threshold (above 5 cm of breast height diameter). Besides recording data on the location of damage, the following data were gathered: amount of damage, size of damage, place of damage and cause of damage. With that we had to determine the tree type, breast height diameter and its economic value. Damage per type of damage was classified as crushed bark or bark peel-off. Crushed bark is damage where the wood cambium zone is not visible and the surface layer of the bark has been removed. Bark peel-off represents damage where the wood cambium zone is visible. Recordings were done in June 2018. During this research, damage was analysed after the work phases had been completed.

During data processing, the degree of tree damage and the forecast of its health status was to be determined. That is why it was necessary, even after the recording of damage, to determine its economic value. Trees were classified in three groups:

1. Selected (tree that by its characteristics should be selected and which has large value considering the possibility to use the wood mass)
2. Useful (tree that does not have large economic value considering the possibility to use the wood mass but it is useful because it helps other growing trees)

⁴ Source: <https://www.google.ba/search?q=GOOGLE+EARTH+PRO&aqs=chrome..69i57ja15.81751j7&sourceid=chrome&ie=UTF-8>

3. Irrelevant (tree which regardless of the damage is of bad physiological status and, with that, does not have any positive influence/impact on selected trees).

Since we performed recordings and sizes of damage, based on that, trees were divided according to degree of damage. According to the degree of damage, the trees were divided into:

1. Very severely damaged (trees, whose damage is such that there is no chance of recovery from gained wounds),
2. Severely damaged (trees, whose damage is such that there is a possibility to recover from gained wounds but the damage is such that there will be no significant use of the tree considering the possibility to use the tree in the economy) and
3. Insignificantly damaged (trees, whose damage is such that the tree it self will very quickly recover from its wounds),
4. Undamaged trees.

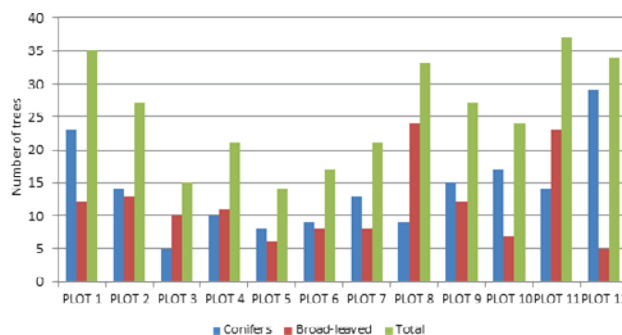
Set test plots were not close to truck roads, therefore, there was no damage during remote transport with loading, and also plots were not close to landings.

RESULTS REZULTATI

The results represent part of the research during the felling and wood extraction phases using the LKT 81 skidder in uneven aged forests in the area of Forestry Kupres.

Types of damaged trees – Vrste oštećenih stabala

Damage was recorded on 166 conifer trees and 139 broad-leaved trees. Out of the total number of damaged trees of



Graph 1 Distribution of damaged trees per plots and total in compartment 174/b

Grafikon 1. Raspored oštećenih stabala prema ploham i ukupno u odjelu 174/b

conifers, 133 are fir trees, 33 are spruce trees, 130 beech trees and 9 trees of other broad-leaved species. Intensity of damage, i.e. ratio of damaged and healthy trees is 18.9 % (table 1.).

If we add the trees that have only old damage to these trees, then it would be necessary to add to the above-mentioned trees a total of 191 tree, and then the intensity of damage would be 30.62 % i.e. almost every third tree would be damaged.

The number of damaged trees is represented in graphic (graph 1.).

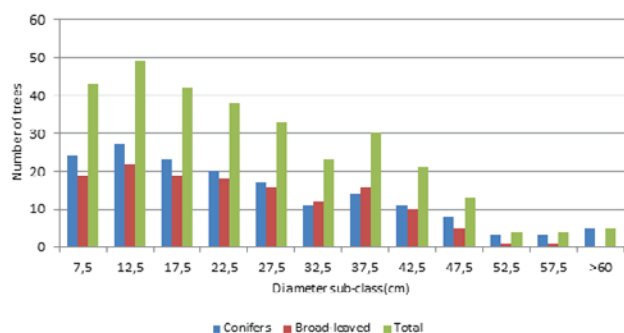
Breast height diameter of damaged trees – Prsni promjer oštećenih stabala

During the research, we recorded 10 damaged trees with the lowest breast height diameter of 6 cm on breast height, and the damaged tree with the highest breast height diame-

Table 1 Number of damaged trees per tree type

Tabela 1. Broj oštećenih stabala prema vrstama drveća

Plots <i>Plohe</i>	Number of trees after felling <i>Broj stabala nakon sječe</i>	Conifers Četinjače		Broad-leaved Listače		Total <i>Ukupno</i>
		Fir <i>Obična jela</i>	Spruce <i>Obična smreka</i>	Beech <i>Obična bukva</i>	Other broad-leaved <i>Ostale listače</i>	
PLOT 1	158	20	3	11	1	35
PLOT 2	133	12	2	13	0	27
PLOT 3	120	3	2	10	0	15
PLOT 4	116	9	1	10	1	21
PLOT 5	86	6	2	6	0	14
PLOT 6	101	6	3	5	3	17
PLOT 7	103	11	2	8	0	21
PLOT 8	127	5	4	22	2	33
PLOT 9	156	11	4	12	0	27
PLOT 10	150	12	5	7	0	24
PLOT 11	185	11	3	21	2	37
PLOT 12	175	27	2	5	0	34
Σ	1,610	133 (43.7%)	33 (10.8%)	130 (42.6%)	9 (2.9%)	305 (100%)



Graph 2 Distribution of damaged trees as per diameter sub-class for conifers, broad-leaved and total

Grafikon 2. Raspored oštećenih stabala prema debljinskim stupnjevima za četinjače, listače i ukupno

ter was 65 cm. The distribution of damaged trees per diameter sub-class is presented on graph 2.

The largest number of damaged trees is in the diameter sub-class of 12.5 cm and 7.5 cm. Smaller size damage is in larger diameter sub-classes.

Cause of damage – *Uzrok oštećenja*

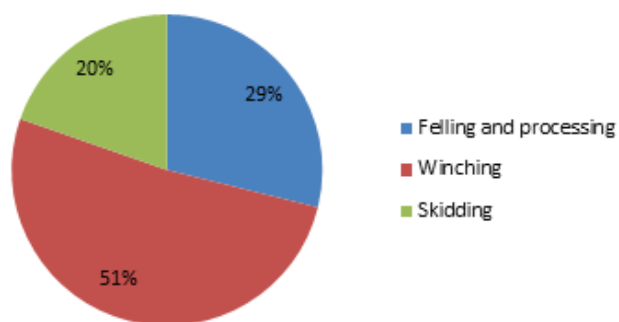
Damage was classified in the following manner regarding the causes of said damage: damage which appeared during felling and processing, damage which appeared during winching and damage which appeared during skidding of wood. Distribution of damage per cause of damage is provided in graph 3.

In the presented graph, it is visible that damage that occur on trees are mostly caused during the winching phase, which makes over 50% of all damage.

Size of wounds/damage – *Veličina ozljeda/oštećenja*

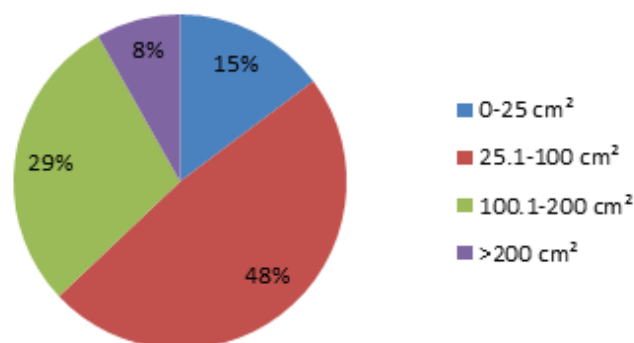
Damage per size was divided into four categories: 0-25 cm², 25.1-100 cm², 100.1-200 cm² and >200 cm² according to the methodology used by Tavankar et al. (2017). The data on damaged trees per size of the wound in compartment 174/b is depicted in graph 4.

In the presented graph, it can be noticed, that most damage occurred with wounds in size of 25.1 – 100 cm², while the



Graph 3 Ratio of damaged trees considering the cause of damage

Grafikon 3. Odnos oštećenih stabala prema uzroku oštećenja



Graph 4 Distribution of damaged trees regarding the size (area of) of the wound

Grafikon 4. Struktura oštećenih stabala prema veličini (površini) ozljede

smallest amount of damage was the one with area of damage over 200 cm².

The average size of the wound in total on all plots is 92.26 cm². On the surface, the largest wound occurred during extraction and amounted to 350 cm², while the smallest wound occurred during felling and amounted to 5 cm².

Place of damage – *Mjesto oštećenja*

During research we determined the type of damage that appears on trees regarding the place. Under type of damage we understand the type of wound and in that case, we considered three types of damage. Those are wounds which appeared by contusion of bark (wood cambium not visible), wounds which appeared by removing of a dead part (visible wood cambium) and combined wounds.

The appearance of damage regarding the type (crushed bark, bark peel-off, combined) and place of damage (stem, butt end, root collar or root) is depicted in the following images and values of gained data are provided in graph 5.

According to the data presented in graph 5, it is noticeable that the largest number of all forms of wounds/damage is located on butt end, while the smallest amount of damage can be seen on the root.

Management value of damaged trees – *Gospodarska važnost oštećenih stabala*

For each damaged tree we evaluated its management value (selected, useful and irrelevant) (graph 6.).

Out of 305 damaged trees, 112 trees (36.7%) belong to the category Selected tree, 115 trees (37.8%) belong to the category Useful tree and 78 trees (25.6%) belong to the category Irrelevant tree.

Status of damaged trees – *Stanje oštećenih stabala*

During the analysis of trees regarding the degree of damage, all trees were divided into three (3) categories: very severely damaged, severely damaged and insignificantly damaged (graph 7.).



Figure 5 Old damage
Slika 5. Staro oštećenje
Foto: (Šarić, M.)



Figure 6 Damage to root and root collar
Slika 6. Oštećenje korijena i žilišta
Foto: (Šarić, M.)

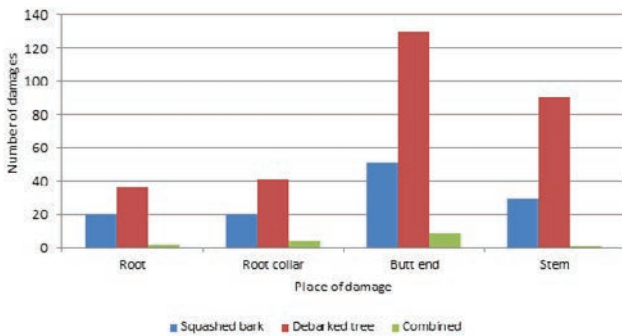


Figure 7 Damage to butt end
Slika 7. Oštećenje pridanka
Foto: (Šarić, M.)

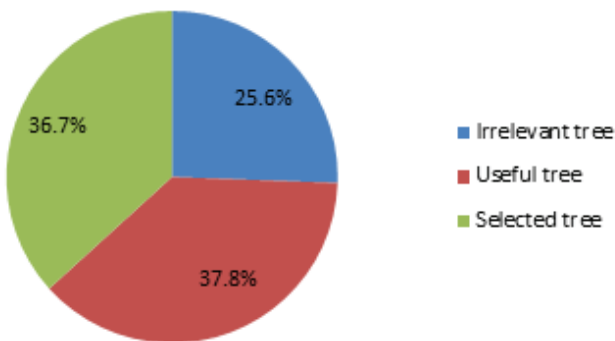


Figure 8 Damage to stem
Slika 8. Oštećenje debla
Foto: (Šarić, M.)

In Graph 7, it is visible that a total of 66 trees (21.7%) are in the category of very severe damage, 127 trees (41.6%) in the category of severe damage and 112 trees (36.7%) belong to the category of insignificant damage.



Graph 5 Distribution of damaged trees regarding the type and place of damage
Grafikon 5. Raspored oštećenih stabala prema vrsti i mjestu oštećenja

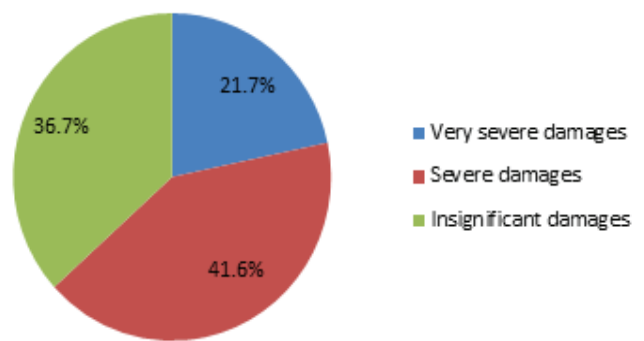


Graph 6 Ratio of damaged trees regarding its management value
Grafikon 6. Odnos oštećenih stabala prema njihovoj gospodarskoj važnosti

DISCUSSION RASPRAVA

Through an analysis of damaged trees per plots, it can be determined that the most trees were damaged on plots 1, 8, 11 and 12 (graph 1). The main reason of such damage to trees per plots is in the organisation of work and position and characteristics of the plot itself. We can assume that the workers who performed the operation of forest utilisation on the mentioned plots, were not careful during their performance as they were on other plots, because these plots are further away from the truck road and this is most likely the main reason of larger damage on trees per plots. Also, parts of these plots, when observed from the aspect of terrain characteristics, are less favourable than other plots and thereby more damaged trees appeared on these plots.

When we analyse the distribution of damaged trees per diameter sub-classes we can determine that the largest number of damaged trees is in diameter sub-class of 12.5 cm,



Graph 7 Ratio of damaged trees regarding the degree of damage
Grafikon 7. Odnos oštećenih stabala prema stupanju oštećenosti

while only five (5) damaged trees over 60 cm breast height diameter. Other researchers reached the same results.

According to the research by Sabo (2003), the largest number of damaged trees is in the diameter sub-classes of 12.5 cm and 17.5 cm. Veselinović (2012) determined that the largest number of damaged trees is in the diameter sub-class of 12.5 cm, while in the research of Zahirović et al. (2016), the largest number of damaged trees is in diameter sub-class of 17.5 cm.

When we analyse the damage regarding the case of damage, then the largest amount of damage happens during the second phase of forest utilisation i.e. the phase of skidding and winching. According to this research, we recorded 88 trees or 29% that were damaged during felling and processing and 217 or 71% trees during the phase of wood extraction i.e. 157 or 51% trees during the winching phase and 60 or 19% trees during the skidding phase. According to the research by Danilović et al. (2015), the largest number of damaged trees is caused during tree felling (around 50%), while according to the research by Tavankar et al. (2013), the greatest amount of damage happened during the extraction phase (74.4%), while during the felling and processing phases 25.6% damage occurred. The differences that appear in these researches can be the result of various factors.

The analysis of damage per size shows that damage in size of 25.1-100 cm² is the most common.

The average size of the wound caused during felling is 79.51 cm², the average size of the wound caused during winching is 109.87 cm² and the average size of the wound caused during skidding is 90.75 cm². When we compare these results with the results of other research, then we can spot significant differences.

According to the research by Sabo (2003), the smallest height of the wound from the ground is 10 cm, and the largest is 275 cm.

In the research by Tavankar et al. (2015), the largest number of wounds ranges from 11-50 cm² (46%), and the smallest appears in a range over 201 cm².

In the research by Zahirović et al. (2016), it was determined that the greatest amount of damage appears over 100 cm².

According to the research by Veselinović (2012), the average size of wounds caused during approaching with cable-skidder with winch is 1,104 cm², and during extraction with animal is 465 cm². The differences, that appear in these researches, most likely are caused by different stand characteristics and the non-implementation of appropriate protective measures during forest utilisation as protection of trees next to skids.

The most common type of damage according to place of damage, is damage to butt end, and the least common is damage to the root. According to the damage type, the most common is damage that caused the removal of bark.

Vondra and Bogojević (1994) determined that 78% of damage out of all damage occurs on the height of 1 m from the ground.

According to Sabo (2003), the largest amount of damage was on root buttress 84 to 91% while other tree parts (root, stem) were less damaged.

In the research by Zahirović et al. (2016), the largest amount of damage appears in the area of butt end and root collar (72%).

Also, according to the research by Tavankar et al. (2013), the largest amount of damage appears in the area of butt end (57%), and in the research by Veselinović (2012), damage is also on the butt end (53%).

The largest percentage share of damaged trees is in the category of useful tree (37.8%), then in the category selected tree (36.7%). Similar results were reached by Veselinović (2012) who determined that the largest number of damaged trees is with characteristics of selected trees (44%), while the smallest are those categorised into irrelevant trees (23%). Sabo (2003) determined that there were 46% of damaged selected trees, 30% of useful, and 24% of irrelevant trees on object A, and on object B there were 35% of selected trees, 42% of useful and 23% of irrelevant trees.

The largest share of trees that suffered very severe damage are in the category of trees that have a surface of the wound larger than 150 cm², while the share of those trees that suffered insignificant damage are in the category of trees that have the surface of the wound smaller than 50 cm². In the research by Veselinović (2012), the largest number of damaged trees belongs to severely damaged trees (38%), while the smallest number of damaged trees is in the group of very severely damaged trees (28%). These results are similar to the results reached in this research. According to research by Sabo (2003), there was a percentage of 53% very severely damaged trees on object A, 41% of severely damaged trees and 6% of insignificantly damaged trees. On object B, there was a percentage of 47% of very severely damaged trees, 47% of severely damaged trees and 6% of insignificantly damaged trees.

CONCLUSIONS ZAKLJUČCI

During the operations of felling and extraction of wood, unavoidable damage is caused to the remaining trees. In addition, there is damage that could be avoided with the application of proper technology and methods of work, selection of work assets, change of relationship of worker and manager towards work, forest and damage to the stand.

In this research, the total amount of recorded damage is 305 trees, 133 trees of silver fir, 130 trees of European beech, 33 trees of European spruce, 8 trees of rowan and one tree of sycamore.

Overall damage intensity was 18.9%, and when we add to this the old damage, the overall number of wounds is 496 (30.6%).

The largest amount of damage is in the diameter sub-class ranging from 10 to 15 cm.

According to the cause of damage, the largest amount of damage occurred during the wood extraction phase (217 trees).

Important factors influencing the occurrence of damage in the winching phase are the experience and training of workers. The amount of damage could be lowered in this case through additional worker training, especially in the case of selecting the skidding direction and load formation.

It is necessary to increase control in the performance of all operations in forest utilisation, modernise machines used in forest utilisation and in quality way open compartments with forest transport infrastructure.

With a series of indicators on damage and wounds to the stand, we have confirmed the assumption that stand and terrain conditions are deciding/determining factors of damaging, with equal other conditions – technology and methods, work assets and work executioners. With that, we additionally confirmed the need to develop work qualification of stands for the purpose of modelling of standardised dynamic measures and measures to validate quality of performed works in forests. Without those solutions it will not be possible to improve (or just introduce) the system of valuation of complex efficacy of getting wood and other work (production) processes in forestry.

REFERENCES LITERATURA

- Akay A., Yilmaz M., Tongue F. 2006. Impact of mechanized harvesting machines on forest ecosystem: Residual stand damage. *Journal of Applied Sciences*, 11:2414-2419.
- Badraghi N., Erler J., Hosseini S.A.O. 2015. Residual damage in different ground logging methods alongside skid trails and winching strips. *Journal of Forest Science*, 61(12): 526-534.
- Behjou F.K. 2016. Economic Analysis of Residual Tree Damage Following Selection Logging in a Caspian Hardwood Forest. *Global Journal of Agricultural Innovation, Research and Development*, 3, 23-27.
- Calcante, A., Facchinetti, D., Pessina, D., 2018: Analysis of Hazardous Emissions of Hand-Operated Forestry Machines Fuelled with Standard Mix or Alkylate Gasoline. *Croat. J. For. Eng.* 39(1): 109–116.
- Danilović M. 2015. Damage to residual trees and regeneration during felling and timber extraction in mixed and pure beech stands. *Šumarski list*, 5-6: 253-262.
- Dvorak J., Iordache E. 2010. Estimating the level of trees damage and financial losses by logging. *Bulletin of the Transilvania University of Brasov, Series II, Forestry, Wood Industry, Agricultural Food Engineering*, Vol. 3(52): 37-46.
- Erlogu H., Ozturk O.U., Sonmez T., Tilki T., Akkuzu E. 2009. The impacts of timber harvesting techniques on residual trees, seedlings and timber products in natural oriental spruce forests. *African Journal of Agricultural Research*, 4:220-224.
- Halilović V., Musić J., Bajrić M., Sokolović Dž., Knežević J., Kupusović A. 2019: Analiza potrošnje goriva pri sječi i izradi stabala hrasta kitnjaka na području p.j. Šumarija „Zavidovići“. *Šumarski list*, 7/8: 437-446.
- Hartsough B. 2003. Economics of harvesting to maintain high structural diversity and resulting damage to residual trees. *Western journal of applied forestry*, 15: 1-7.
- Ilintsev, A., Nakvasina, E., Aleynikov, A., Tretyakov, S., Koptev, S., Bogdanov, A., 2018: Middle-Term Changes in Topsoils Properties on Skidding Trails and Cutting Strips after Long-Gradual Cutting: a Case Study in the Boreal Forest of the North-East of Russia. *Croat. J. For. Eng.* 39(1): 71–83.
- Kaminsky E. 1984. Die Mechanisierung der Holzgewinnung in der Polen. Referat na simpozijum Mehanizacija u iskorištavanju šuma, Zalesina, 7- 8: 158-163.
- Karaszewski, Z., Łacka, A., Mederski, P.S., Bembenek, M., 2018: Impact of Season and Harvester Engine RPM on Pine Wood Damage from Feed Roller Spikes. *Croat. J. For. Eng.* 39(2): 183–191.
- Kulušić B. 1977. Iskorištavanje šuma. Proizvodnja šumskih sortimenata. *Šumarski fakultet u Sarajevu*.
- Kulušić B. 1990. Karakteristike šumskih terena kao indikatora izbora tehnologije privlačenja drveta. *Šumarski list*, 11-12: 463-473.
- Labelle, E.R., Lemmer, K.J., 2019: Selected Environmental Impacts of Forest Harvesting Operations with Varying Degree of Mechanization. *Croat. J. For. Eng.* 40(2): 239–257.
- Martinić I. 1991. Oštećenje sastojine pri obradi stabala, izradi i privlačenju drva. *Šumarski list*, 1-2: 33-49.
- Marusiak, M., Neruda, J., 2018: Dynamic Soil Pressures Caused by Travelling Forest Machines. *Croat. J. For. Eng.* 39(2): 233–245.
- Meng W. 1978. Eine Methode zur Erfassung von Ruckenschaden. *Forsttechnische Informationen* 12.
- Ostrofsky W.D. 1988. Improving tree Quality and Forest Health by Reducing Logging Injuries, in *Proceedings of Mains Hardwood Resource: Quantity Resource Quality*. Orono, ME, str. 29-35.
- Petreš, S., 2006: Damages on the Young Plants During the Timber Extraction by Cable Skidder LKT 81 T from the Final Cut of Pedunculate Oak. *Šumarski list* 130(3–4): 87–100.
- Poršinsky T., Ozura M. 2006. Oštećenost dubećih stabala pri izvoženju drva forvarderom. *Šumarski fakultet Sveučilišta u Zagrebu, Nova mehanizacija šumarstva*, Vol 27 (1): 41-48.
- Sabo A. 2003. Oštećivanje stabala pri privlačenju drva zglobnim traktorom timberjack 240c u prebornim sastojinama. *Šumarski list*, 7–8: 335 – 346.
- Solgi A., Najafi A. 2007. Investigating of residual tree damage during ground based skidding. *Pakistan Journal of Biological science*, 10: 1755-1758.
- Solgi, A., Naghdi, R., Labelle, E.R., Tsioras, P.A., Salehi, A., 2018: Comparison of Sampling Methods Used to Evaluate Forest Soil Bulk Density. *Croat. J. For. Eng.* 39(2): 247–254.
- Solgi, A., Naghdi, R., Labelle, E.R., Behjou, F.K., Hemmati, V., 2019a: Evaluation of Different Best Management Practices for

- Erosion Control on Machine Operating Trails. Croat. J. For. Eng. 40(2): 319–326.
- Solgi, A., Naghdi, R., Zenner, E.K., Tsioras, P.A., Hemmati, V., 2019b: Effects of Ground-Based Skidding on Soil Physical Properties in Skid Trail Switchbacks. Croat. J. For. Eng. 40(2): 341–350.
 - Tavankar F. 2013. Felling and skidding damage for residual trees following selection cutting in Caspian forest of Iran. Journal of science, 59 (5): 196-20.
 - Vasiliauskas R. 2001. Damage to trees due to forestry operations and its pathological significance in temperate forest. Forestry, 74: 319-336.
 - Veselinović T. 2012. Mehanička oštećenja dubećih stabala i podmlatka kao posljedica operacija iskorištavanja šuma na području SGP „Igmansko“ Magistarski rad, Šumarski fakultet u Sarajevu. str. 1-59.
 - Vondra V., Bogojević S. 1994. Prinos znanju o uporabi srednjeg skidera Ecotrac V organizacijskim i ekonomskim pokazateljima rada, Mehanizacija šumarstva, 19 (4): 247-258.
 - Zahirović K., Treštić T., Mujezinović O., Hasković A. 2016. Utjecaj sječe i izrade drvene mase na oštećenost i zdravstveno stanje stabala smreke i jele na području planine Zvijezda. Naše šume, 44-45: 15-29.
 - Anonimus 2018. Management plan for forest compartment 174/b MU „Hrbinje-Kujača“
 - Anonimus 2019. Federalno ministarstvo poljoprivrede, vodoprivrede i šumarstva <https://fmpvs.gov.ba>

SAŽETAK

Mehanizacija koja se koristi u iskorištavanju šuma utječe na pojavu oštećenja u sastojini i na šumskom tlu. Istraživanja u ovom radu su imala za cilj utvrđivanje oštećenja na stablima jele i drugih vrsta drvca pri sječi i izradi drvnih sortimenata te privlačenju šumskim zglobnim traktorom.

Istraživanja su obavljena u mješovitim šumama bukve i jele sa smrekom na području ŠGP „Glamočko“, G.J. „Hrbinje-Kujača“.

Prikupljeni su sljedeći podaci o oštećenim stablima: vrsta drveća, prsni promjer stabla, privredna važnost stabla, broj oštećenja, mjesto oštećenja, uzrok oštećenja, vrsta oštećenja.

Oštećenja su evidentirana kod ukupno 305 stabala, 133 stabala jele (*Abies alba*), 130 stabala bukve (*Fagus sylvatica*), 33 stabla smreke (*Picea abies*), osam stabala jarebice (*Sorbus aucuparia*) i jedno (1) stablo gorskog javora (*Acer pseudoplatanus*). Ukupan intenzitet oštećenja je iznosio 18,7%, a kad tome pridodamo i stara oštećenja, ukupan broj ozljeda iznosi 496. Prema tomu, kada se u obzir uzmu i stara oštećenja, tada intenzitet oštećenja iznosi 30,6%. Najveći broj oštećenja se nalazi u debljinskom stepenu od 10 do 14,99 cm.

Prema uzroku oštećenja, najveći broj oštećenja je nastao prilikom faze privlačenja (217 stabala), dok je prilikom sječe oštećeno 88 ili 29% stabala. Kako je faza privlačenja podijeljena na fazu primicanja i privlačenja, ukupan broj oštećenih stabala tijekom faze primicanja iznosio je 157 ili 52%, dok je tijekom privlačenja broj oštećenih stabala iznosio 60 ili 19%.

Da bi se prilikom sljedećih operacija iskorištavanja šuma smanjile štete na stablima, potrebna je češća edukacija svih djelatnika koji obavljaju poslove iskorištavanja šuma, potrebno je povećati kontrole obavljanja svih poslova prilikom iskorištavanja šuma, modernizirati strojeve koji se koriste prilikom eksploatacije šuma te na kvalitetan način otvoriti odjele šumskim komunikacijama.

KLJUČNE RIJEČI: jela, smreka, bukva, sječa, privlačenje, oštećenje.