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DAMAGE TO RESIDUAL TREES AND REGENERATION DURING FELLING AND TIMBER EXTRACTION IN MIXED AND PURE BEECH STANDS

OŠTEĆENJA NA PREOSTALIM STABLIMA I POMLATKU TIJEKOM SJEČE I PRIVLAČENJA DRVA U MJEŠOVITIM I ČISTIM BUKOVIM SASTOJINAMA

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Summary

This paper presents an analysis of damage to residual trees and the regeneration that occurs during harvesting using the half tree length method and timber extraction in winter operating conditions in a pure beech stand and a mixed stand of beech fir and spruce in the territory of the Srpska Republic. In this study, types of damage were investigated, as well as the size of wounds. Felling and processing of wood assortments were performed with a chainsaw and timber extraction on earth and by skid trail to a roadside landing on a truck road was performed with a tractor Timberjack 240C. The number of injuries that occurred during the felling and transport of trees in the mixed stand was on average 2.69 wounds per felled tree, whereas in the pure stand the average number of wounds per felled tree was 2.27. During the felling of trees in both sample plots, the largest number of injuries was to the crowns of neighbouring trees, which was followed by damage to the butt end, whereas the lowest number of injuries was incurred to the root collar. During the timber winching, the most common damage was to the root collar, whereas during timber skidding the most common type of damage was to the butt end. Damage to the regeneration was evident in both sample plots in the form of breakages of plants and their branches, as well as uprooting of whole plants. Damage to the butt end and root collar that occurred at the felling stage was in the form of bark peeling and other superficial wounds whose most common sizes were larger than 200 cm^2. The average area of injuries caused during the transport phase ranged from 50 to 200 cm^2.

KEY WORDS: damage, mixed and pure stands of beech, skidder, felling and processing of wood assortments, timber extraction.

INTRODUCTION
UVOD

During mechanized felling and timber extraction damage occurs to residual trees, the regeneration and the soil. A large number of researchers have investigated the size, number and location of wounds incurred in this way (Petreš 2006; Solgi and Najafi 2007; Košir 2008; Gerasimov and Katarov 2010; Kuramoto et al. 2010).

The type and size of damage that occurs during felling, processing and timber extraction depends on the number of

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trees in a stand, regeneration density, felling intensity, diameters of trees, sizes of crowns, felling direction, slope of the terrain, the method of wood assortment processing and the operator's skills. However, it also depends on the density of the primary and secondary road networks. The occurrence of damage to trees has a particular significance in even-aged and uneven-aged stands, where only a part of the standing volume is removed by felling (Ostrofsky 1988). Damage to trees and the regeneration occurring at the stage of felling and transport of timber represents one of the most stressful events in forest management (Dvorak and Iordache 2010). Tree wounds are often suitable areas for the emergence of various diseases that can cause physiological decline of trees (Vasiliauskas 2001), and quality of the residual trees is an important factor of the future stand value (Bobik 2008).

Elements of the proposed systems of felling should be harmonized with respect to the characteristics of the forest, type of machinery and felling intensity, in order to include variable factors that affect the efficiency of work (Akay et al. 2004). As a result of damage caused to trees, soil and ground vegetation, timber extraction is considered the most delicate stage of operation in forestry, especially in protected areas.

In order to reduce damage to residual trees and the regeneration during the operations of felling, processing and transport of wood assortments, it is necessary to pay attention to directional tree felling and choice of an adequate skidding facility (Campbell 2003), as well as proper distribution and density of forest road infrastructure.

The choice of technique and technology of work has marked impact on the degree of damage to residual trees, the regeneration and assortments (Eroglu et al. 2009). Some authors have pointed out that the timber extraction with skidders in areas with steep slopes (50 – 70%) leads to significant damage, and that the best solution on such a terrain is a cable yarder. Spinelli et al. (2010) found 12-14% of damaged trees in a stand when conventional felling and timber extraction with adapted agricultural tractors were applied.

A number of researchers (Limbeck-Lilienau 2003; Poršinsky and Ožura 2006; Solgi and Najafi 2007; Tsorias and Liamas 2010, etc.) have investigated damage to residual trees in the stand after the technological processes of felling and transport. Most of these researchers used classification of the type of damage after Meng (1978).

According to the research of Solgi and Najafi (2007) in the forests of beech and hornbeam in Iran, during the timber extraction with a skidder, the most common type of damage is to the root of residual trees, accounting for as much as 41% of the total damage. The authors point out that during timber extraction in mixed stands, thick and forked branches should be removed, because in this way, damage to residual trees is significantly reduced. According to the research Danilović et al. (2011) the notching and bending of thick branches can significantly decrease damage to residual trees in a stand.

Tsorias and Liamas (2010) observed that during the transport of wood assortments in mixed forests of beech and oak by skid trail with an adapted agricultural tractor, most injuries occur to the stem in the area of up to 2 meters on

Figure 1. Map of the spatial position of the Čajniče Municipality
Slika 1. Karta prostornog položaja općine Čajniče

Table 1. Number of plants in the regeneration
Tablica 1. Brojnost pomlatka

Tree species *Vrsta drveća*	Sample plot 1 *Pokusna površina 1*				Sample plot 2 *Pokusna površina 2*			
	Height *Visina*			Total *Ukupno*	Height *Visina*			Total *Ukupno*
	10–50	50–130	>130		10–50	50–130	>130	
	cm			Piec.·ha^{-1} Kom·ha^{-1}	cm			Piec.·ha^{-1} Kom·ha^{-1}
Fir	4.773	800	503	6.076	–	–	–	–
Spruce	2.714	611	332	3.657	–	–	–	–
Beech	3.621	708	228	4.557	10.616	2.621	–	13.237
Conifers	7.487	1.411	835	9.733	–	–	–	–
Broadleaves	3.621	708	228	4.557	10.616	2.621	–	13.237
Total	11.108	2.119	1.063	14.290	10.616	2.621	–	13.237

both sides of the trail. The area of these wounds in the form of bark peeling is larger than 200 cm^2.

The aim of this study is to determine the number and size of wounds to residual trees and the regeneration in a pure beech stand and a mixed stand of beech, fir and spruce, when the half tree length method of felling and processing is applied. In addition, another aim of this paper is to the rank the types of damage occurring during the operations of logging and timber extraction according to their frequency of occurrence.

MATERIALS AND METHODS
MATERIJALI I METODE

The research was carried out in November and December 2009 in a pure beech stand and a mixed stand of beech, fir and spruce, in two sample plots located in the Municipality of Čajniče in the Srpska Republic (Figure 1).

Sample plot 1 (SP1) is located in a high mixed stand of beech, fir and spruce on deep acid brown soils. The stand has a group selection structure with the regeneration densely distributed in groups. The shares of species in the mixture are as follows: 67% spruce, 21% beech, 11% fir and other broadleaved species 1%. The area of the sample plot is 47.30 ha, and the wood volume is 416 $m^3 \bullet ha^{-1}$. The intensity of felling is 11.95% for conifers and 12.99% for broadleaves. The terrain is steep and dissected, with an altitude ranging from 1000 to 1200 m, a south-southeast aspect, whereas the density of the secondary road network reaches 50.7 $m \bullet ha^{-1}$.

Sample plot 2 (SP 2) is located in a high beech stand on deep acid brown soil. The area of the sample plot is 55 ha. The group selection forest management method is applied in this stand. The regeneration density is medium, wood volume reaches 345 $m^3 \bullet ha^{-1}$ and the intensity of felling amounts to 13.52%. The terrain is steep, with a slope of up to 70%, the altitude ranges from 750 to 1050 m, the aspect is western and the secondary road network density is 45.8 $m \bullet ha^{-1}$.

The regeneration density in the two sample plots differed (Table 1).

All trees located in the zone of risk of damage from felling and timber extraction were analyzed, and grouping was performed by tree species and 5 cm diameter degrees.

The operations of felling and processing of wood assortments were performed with a chainsaw. The half tree length method of wood assortment processing was applied along with the group system of work.

The extraction of logs and thick branches was carried out with a tractor Timberjack 240C on earth to skid trails (timber winching) and by skid trail to a truck road and a roadside landing (timber skidding).

All injuries incurred during tree harvesting and timber extraction were measured in the sample plots. In the felling phase, the number of injuries was expressed as the average number of injuries per felled tree, and in the phase of transport as the number of wounds per winching operation. According to the place of formation, the wounds were divided into damage to standing trees and damage to the regeneration. The injuries to standing trees were classified into four groups: damage to the stem (various breakages, tree topping and uprooting), damage to the butt end (bark peeling and other superficial wounds), damage to the crown (breakages, peeling and wounds to branches) and damage to the root collar (bark peeling and other superficial wounds to the root collar). Damage to the regeneration most frequently occurs in the form of breakage of plants and branches, as well as uprooting of the whole tree. Damage to the soil was not analyzed.

The size of wounds (bark peeling) was determined by measuring the height and width of injuries, on the basis of

Table 2: Number of trees and characteristics of wood assortments in sample plots
Tabela 2: Broj stabala i karakteristike drvnih sortimenata na pokusnim površinama

Sample plot *Pokusna površina*	Number of analyzed trees *Broj analiziranih stabala*		Average number of assortments per tree (piece/tree) *Prosječan broj komada po stablu (kom/stablu)*		Average length of assortments (m) *Prosječna dužina komada (m)*	
	Broad-leaves *Listače*	Conifers *Četinjače*	Broad-leaves *Listače*	Conifers *Četinjače*	Broad- leaves *Listače*	Conifers *Četinjače*
SP 1 *OP 1*	83	143	4.1	2.3	7.4	8.9
SP 2 *OP 2*	101	–	4.7	–	7.6	–

which wound areas were calculated and expressed in cm^2. Wounds measured on every tree were used to calculate both the average area of wounds incurred during tree felling and the average area of injuries occurring during the transport of wood assortments.

RESULTS
REZULTATI

The number of analyzed trees, the average number of produced assortments and the average length of assortments are shown in Table 2.

Felled trees were processed by bucking into logs of optimal length for extraction and in order to reach the maximum financial effect from the aspect of the national quality standards for roundwood.

The first phase of transport in SP1 was carried out in November at an average morning temperature of 1.5 °C measured at 07:00 h and a daily temperature of 6.1 °C measured at 13:00 h in SP2. The timber extraction was carried out in December at an average morning temperature of 4.3 °C and a daily temperature of 8.8 °C. Skidding was performed downhill by 3 m-wide skid trails.

During the felling of trees and transport of wood assortments, the total number of injuries in the mixed stands (SP1) amounted to 610 in a total of 226 inspected trees, i.e. an average of 2.69 wounds per inspected tree (1.41 wounds to standing trees and 1.28 wounds to the regeneration). In the pure stand (SP2) a total of 101 trees were felled, which caused 229 injuries, i.e. 2.27 wounds per inspected tree (1.84 wounds to standing trees and 0.43 wounds to the regeneration). Out of the total number of inspected trees in the mixed stand, 138 trees were the cause of damage i.e. 61 % of them, while in the pure stands the number of damage causing trees amounted to 60, i.e. 59 % of the total number of trees.

Damage incurred in the felling phase – *Oštećenja nastala tijekom sječe*

Considering the number of injuries to residual trees in the stand, damage to the crowns of neighbouring trees was observed as the most common type of damage in both sample plots (Figure 2). A total of 169 wounds (0.75 per tree) were recorded in the mixed stand and in the pure stand that number was 77 (0.77 per tree).

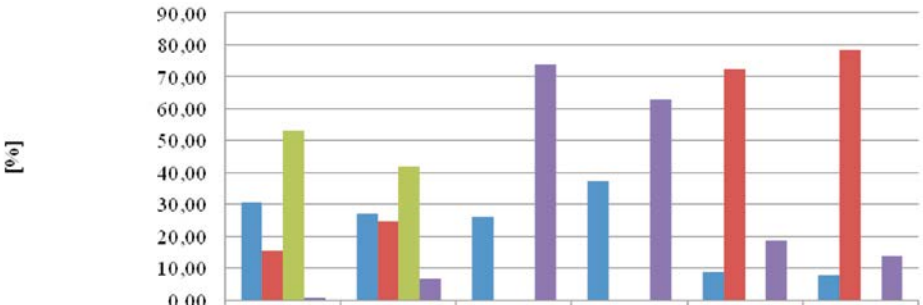
In both sample plots, damage to the stem was the second most significant type of damage as regards the frequency of occurrence. Damage to the stem occurred in 98 trees (0.43 wounds per tree) in the mixed stand and in 50 trees in the pure stand (0.50 wounds per tree).

Next in importance regarding the frequency of occurrence is damage to the butt end. In the mixed stand, this type of damage was found in 50 trees (0.22 wounds per tree), and in the pure stand in 45 trees (0.45 wounds per tree).

During felling the lowest number of wounds observed was to the root collar of trees. In SP1 this type of damage was observed in only three trees (0.01 wounds per tree), and in SP2 in 12 trees (0.12 wounds per tree).

Table 3: Transport of wood assortments
Tablica 3: Transport drvnih sortimenata

Sample plot *Pokusna površina*	Number of transport cycles *Broj transportnih ciklusa*	Average transport distance (m) *Prosječna transportna distanca (m)*		Average longitudinal slope of skid trail *Prosječan podužni nagib traktorske vlake*	Average speed of tractor movement by trail *Prosječna brzina kretanja traktora po vlaci*	Density of a secondary road network *Gustoća sekundarne mreže puteva*
	Cycle *Ciklus*	Skid trail *Traktorska vlaka*	Winch *Vitlo*	%	m/min	m/ha
SP 1 *OP 1*	44	800	12.8	20	39.5	60.67
SP 2 *OP 2*	36	600	12.5	16	66.4	45.76



	SP 1 - Felling OP 1 - Sječa	SP 2 - Felling OP 2 - Sječa	SP 1 - Winching OP 1 - Sakupljanje	SP 2 - Winching OP 2 - Sakupljanje	SP 1 - Skidding OP 1 - Privlačenje	SP 2 - Skidding OP 2 - Privlačenje
Damage to the stem Oštećenja na stablu	30,50	27,18	26,15	37,21	8,75	7,69
Damage to the butt end Oštećenja na deblu	15,60	24,45	0,00	0,00	72,50	78,46
Damage to the crown Oštećenja na krošnji	53,19	41,84	0,00	0,00	0,00	0,00
Damage to the root collar Oštećenja na žilištu	0,71	6,53	73,85	62,79	18,75	13,85

Figure 2: Damage to residual trees in the stands
Slika 2: Oštećenja na preostalim stablima u sastojini

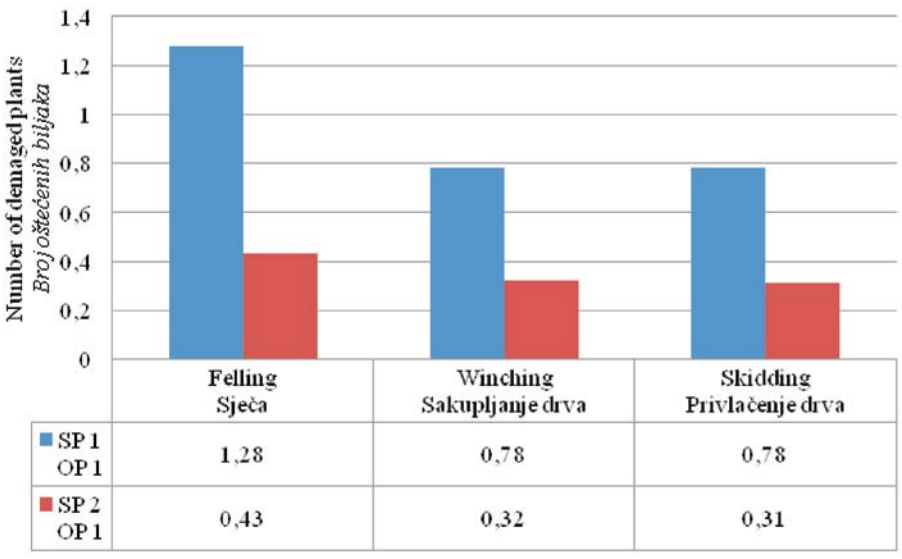
The number of damaged plants in the regeneration was 290 in the mixed stand, i.e. 1.28 wounds per felled tree, and 44 in the pure stand, i.e. 0.43 wounds per tree.

Damage to the butt end and the root collar of standing trees is mainly manifested in the form bark peeling and other surface wounds to the tree. The average wound areas are 390 cm^2 in the mixed stand and 240 cm^2 in the pure stand. Bark peeling larger than 200 cm^2 accounts for 52.6 % of the total number of injuries in the pure beech stand and 43.4 % in the mixed stand (Figure 4).

Damage caused during the timber extraction – *Oštećenja nastala tijekom privlačenja drva*

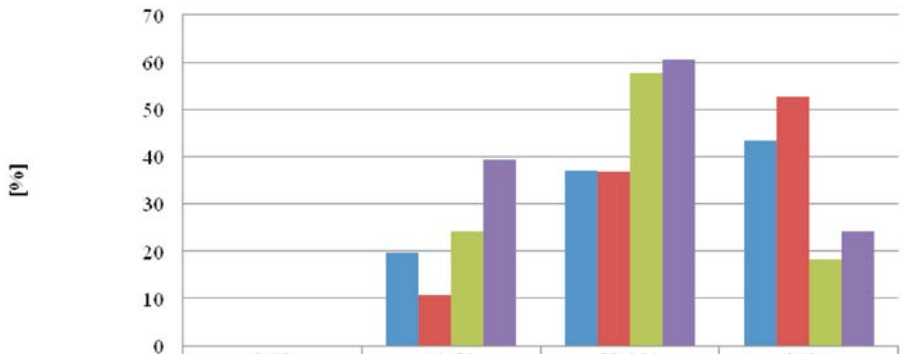
Damage caused during the timber extraction is expressed as the total number of damaged trees, the number of injuries per winching operation and a percentage of the total number of injuries. The number of winching operations was 148 in the mixed stand and 111 in the pure stand.

During the timber winching, the most common type of damage was to the root collar (Figure 2). The number of trees observed with this type of damage was 48 in the mixed



	Felling Sječa	Winching Sakupljanje drva	Skidding Privlačenje drva
SP 1 OP 1	1,28	0,78	0,78
SP 2 OP 1	0,43	0,32	0,31

Figure 3: Damage to the regeneration
Slika 3: Oštećenja na podmlatku



	0-10	10-50	50-200	200>
SP 1 - Felling OP 1 - Sječa	0	19,6	37	43,4
SP 2 - Felling OP 2 - Sječa	0	10,6	36,8	52,6
SP 1 - Transport OP 1 - Transport	0	24,2	57,6	18,2
SP 1 - Transport OP 2 - Transport	0	39,4	60,6	24,2

Figure 4: Size (area) of wounds
Slika 4: Veličina (površina) ozljeda

stand (0.32 wounds per winching operation) and 27 trees in the pure stand (0.24 wounds per winching operation).

Next in importance was damage to the stem. The total of partially or fully uprooted trees was 17 in the mixed stand (0.11 trees per winching operation) and 16 in the pure stand (0.14 trees per winching operation).

Damage to the butt end and crown was not recorded, whereas damage to the regeneration was very pronounced. In the mixed stand, damage to 116 young plants was recorded, i.e. 0.78 damaged plants per winching operation. In the pure stand, the number of damaged plants was 36, i.e. 0.32 plants per winching operation.

In order to determine the percentage of damaged trees along the skid trail, the number of trees in the zone of possible damage was first specified. The length of skid trail in the mixed stand was 900 m and 963 trees were located in the area of increased risk of damage. In the pure stand the length of skid trail was 600 m, and the number of trees counted on both sides of the skid trail was 276.

During the timber skidding to a roadside landing on a truck road, the most common type of damage was to the butt end. The total number of wounds to the butt end in the mixed stand was 116. In other words, 12% of trees located along the skid trail were damaged in this way. In the pure stand, a total of 51 wounds to the bole were recorded, and 18% of trees along the skid trail were damaged.

Damage to the root collar of the trees located along the skid trail was observed in 30 trees in the mixed stand and 9 trees in the pure stand (in both cases about 3% of the total number of trees).

The recorded number of injuries to the stem was 14 (1.45 % of the total number of trees) in the mixed stand, whereas uprooting of 5 trees (1.81 % of the total number of trees) was observed in the pure stand.

In the zone of potential risk of damage along the skid trail, the number of plants counted in the regeneration storey was 669 in the mixed stand and 161 in the pure stand. During the timber skidding, 166 plants (0.78 plants per winching operation) were damaged in the mixed stand, whereas the number of damaged plants in the pure stand was 34 (0.31 plants per winching operation).

Most of the wounds occurring during the timber extraction have areas ranging from 50 to 200 cm^2. The minimum wound area is 12 cm^2, whereas the maximum wound area reaches 600 cm^2. The average wound area is 145.4 cm^2 in the mixed stand and 176.6 cm^2 in the pure stand.

DISCUSSION
RASPRAVA

Trunk parts of coniferous tree species are on average by 18.67% longer than the trunk parts produced from beech trees. Consequently, the number of assortments produced per tree is smaller, which had an impact on the number of pieces in the optimal load.

The results of this survey indicate that there are significant differences in the type and number of incurred injuries between the phases of felling and timber extraction, both

Table 4: Function of dependence of the number of wounds on diameter at breast height
Tablica 4: Funkcije ovisnosti broja oštećenja i promjera stabla na prsnoj visini

Sample plot 1 *Pokusna površina 1*		Sample plot 2 *Pokusna površina 2*
Fir and spruce *Jela i smreka*	Beech *Bukva*	Beech *Bukva*
Function of dependance *Funkcija ovisnosti*		Function of dependance *Funkcija ovisnosti*
$V = 0.0014 \cdot D_{1,3}{}^{2}$ $R^2 = 0.878$, p = 0,000	$V = 0.000014 \cdot D_{1,3}{}^{3,04}$ $R^2 = 0.915$, p = 0.000	$V = \exp(1.58 + 0.045\ D_{1,3}$ $R^2 = 0.815$, p = 0.000

in the pure and mixed stands. However, differences in the frequencies of occurrence of different types of damage within the same phase are not significantly different. The differences that do exist can be explained by the impact of shape and size of the crown on the one hand and the number of trees per unit area on the other.

The number of wounds to residual trees was 1.41 per felled tree in the mixed stand and 1.84 in the pure stand. Therefore, it can be calculated that the number of wounds per tree in the felling phase is by 30.50% higher in the pure stand than in the mixed stand. The explanation for the larger number of injuries in the pure stand may be the fact that the crowns of beech trees are more developed (usually containing forked branches) than the crowns of spruce and fir trees, which leads to deviations from the desired felling direction and major damage to neighboring trees.

In both sample plots, it was found that in the felling phase the most common type of damage is to the crown, which is followed by damage to the stem, damage to the butt end and damage to the root collar (Graph 1). Behjou and Mollabashi (2012) reported 1.35 wounds to the crowns of neighbouring trees per felled tree during felling in an unevenaged beech stand. In a spruce stand in Norway 55% of the trees damaged during felling with chainsaw suffered damage to the crown (Fjeld and Granhus 1998). According to a research performed in Finland (Siren et al. 2015) in uneven-aged spruce stands, almost 70% of the damage incurred during selection cuts with a harvester was to the stem in the form of bark peeling, damage to wood and stem breakage.

Damage to the root collar is the least common due to the fact that during felling the place where the trees fall is usually outside the range of the root collar. Nevertheless, the average number of injuries to the root collar of neighboring trees was significantly higher in the pure stand than in the mixed stand, primarily due to the wider crowns. In addition, it was found that the number of wounds increased with an increase in the diameter of felled trees. This is due to the fact that thicker trees are also higher and have longer and wider crowns, as well as greater wood volume, which makes them more likely to cause damage (Table 4).

A large number of wounds to the regeneration were recorded in the mixed stand during the felling phase. The number of injuries to the regeneration per felled tree was 2.98 times higher in the mixed stand than in the pure stand, as a consequence of higher density of regeneration in the mixed stand. This damage can occur in the form of tree topping, breakage, breaking off of the branches, bark peeling and uprooting of the regeneration. The regeneration in the form of seedlings (young plants) is fairly resistant to bending due to their small height and thin stems. Therefore, after the branches and trunks that fell on them are removed, they can continue with their growth.

In the phase of tree felling, the average wound area is by 62.50% larger in the mixed stand (390 cm^2) than in the pure stand (240 cm^2). Similar results were obtained by Nikooy et al. (2010) who investigated the damage in mixed broadleaf stands, where the average wound size per tree reached 290.31 cm^2. According to a research (Siren et al. 2013) of selection cuts with a harvester in a spruce stand, the average wound area per tree was 71.7 cm^2.

During the phase of timber extraction, damage was recorded to both residual trees and the regeneration. During the timber winching, the most common type of damage was to the root collar of residual trees in the stand. In addition, partial or complete uprooting of trees was observed, while there was no damage to the butt end. The number of injuries to the root collar was by 17.61% higher in the mixed stand than in the pure stand. On the other hand, the number of injuries to the stem was by 42.29% higher in the pure stand than in the mixed stand. In the survey of damage to residual trees in a selection stand of beech, fir and spruce Sabo (2003) reported an 84% share of damage to the root collar in the total number of injuries.

During timber extraction, damage to the regeneration is inevitable. The recorded number of injuries to the regeneration was 2.44 times higher during the timber winching in the mixed stand than in the pure stand. In this case, the explanation may be sought in the number of trees per unit area in the mixed stand. Due to a large number of trees per hectare, in some cases it was necessary to deviate from the skidding direction determined during felling, in order to

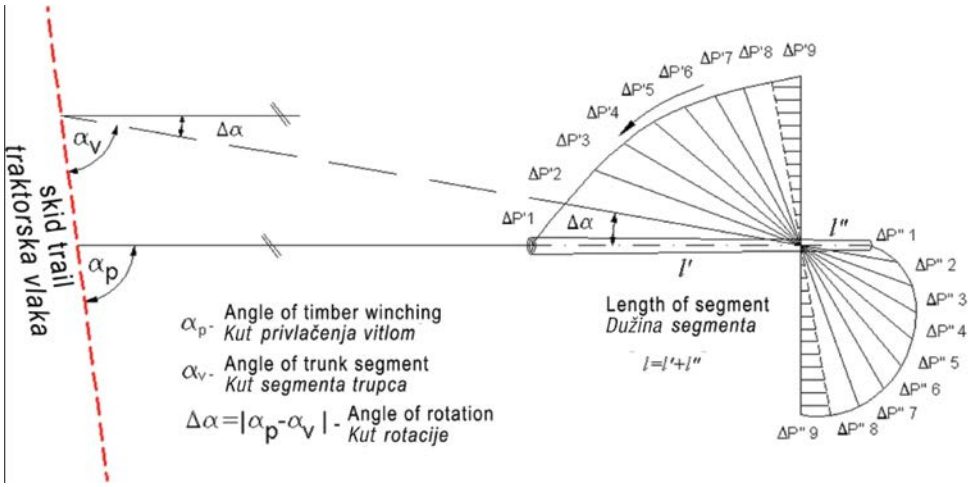


Figure 5: Area of injury depending on the position of the log relative to skidding direction
Slika 5: Površina oštećenja u zavisnosti od položaja trupca u odnosu na pravac privlačenja

minimize the damage. This resulted in a large number of damaged plants. In addition, young spruce plants are less strongly rooted in comparison to young beech trees, which caused a more severe uprooting of the regeneration.

During the timber extraction positioned parallel to contour lines, the assortments usually turn around their axis, which commonly causes injuries to residual trees and the regeneration. The worst case is when the assortments are positioned parallel to skid trail or at an acute angle to the trail to which they are being skid (Figure 5).

If the regeneration height is small, in most cases, there is no severe damage, whereas the situation differs if the plants are tall and large in diameter. If extraction is carried out perpendicular to contour lines, front ends of logs cause damage to plants in the form of bark peeling and uprooting.

After formation of the optimal load, logs were transported to a roadside landing by skid trail. During timber skidding, the front ends of attached assortments were lifted off the ground, while the rear ends of the load had a certain degree of freedom of movement taking the shape of a fan. Therefore, the load became wider than the tractor, which resulted in damage to the stems and the regeneration along the skid trail.

During timber skidding, the most common type of damage to standing trees is damage to the butt end, and much less to the root collar or stems (Figure 2). Injuries to the butt end (bark peeling and superficial wounds) occurred by 8.22 % more frequently in the pure stand than in the mixed stand. The numbers of wounds to the root collar and the stem are higher in the mixed stand than in the pure stand by 35.38 % and 13.78 %, respectively. Uprooting was mainly found in thinner trees with diameters at breast height ranging from 9 cm to 12 cm. On the basis of a research of damage to trees in the timber extraction in beech forests, Behjou (2014) pointed out that out of the total of 489 trees located along the skid trail, 339 trees (69 %) suffered some type of damage.

Damage to the regeneration occurring during the timber skidding does not differ significantly from the damage to the regeneration incurred during winching. In this case, the number of wounds per winching operation was 2.52 times higher in the mixed stand than in the pure stand.

The average area of wounds in the form of bark peeling on the root collar and the butt end during the timber extraction is by 21.46% greater in the pure stand compared to the average area of wounds in the mixed stand. The areas of most wounds range from 50 to 200 cm^2, which represents 57.6 % of all injuries in the mixed stand and 60.6 % in the pure stand. The research results of other authors who have investigated this issue on different tree species and in different conditions indicate that wound areas are most commonly greater than 200 cm^2 (Solgi and Najafi 2007; Ficklin et al. 1997; Tsorias and Liamas 2010). In the research Froese and Han (2006), 84 % of wound areas were smaller than 194 cm^2. If minor wounds are concerned, damaged trees can continue with their growth and they should not be cut down but left to serve as protection to other trees in case of a repeated timber extraction (Doležal 1984).

CONCLUSIONS
ZAKLJUČCI

The following conclusions can be reached on the basis of the results of this survey:

- The number of damages in a stand increases significantly with an increase in the diameter at breast height of felled trees.
- The largest share of damage to residual trees during felling in both the mixed and pure stands is to the crowns

of neighbouring trees (53.19 % of the total number of trees in SP1 and 41.84 % in SP2), whereas the smallest share represents damage to the root collar (0.71 % of the total number of trees in SP1 and 6.53 % in SP2).

- During the timber winching the most common type of damage incurred is to the root collar both in the mixed and the pure stands (73.85 % of the total number of trees in SP 1 and 62.79 % in SP2). This is followed by damage to the stem (26.15 % of the total number of trees in SP1 and 37.21 % in SP2), whereas damage to the crown and butt end was not observed.
- At the stage of timber skidding to a roadside landing on a truck road, the largest number of wounds in both cases was to the butt end of trees along the skid trail (72.50 % of the total number of trees in SP1 and 78.46 % in SP2), which was followed by damage to the root collar and the least damage to the stem.
- Damage to the regeneration is evident both in the phase of felling and during transport. In addition, due to a higher density of seedlings, the number of wounds per felled tree, i.e. per winching operation, is significantly higher in the mixed stand than in the pure stand.
- The degree of damage to the stem is significantly influenced by the direction of assortments in relation to the skid trail direction. The largest number of wounds appears in the case of wood assortments that are parallel to the skid trail.
- During tree felling in both the mixed and pure stands, the most common wounds are the ones whose area is greater than 200 cm^2, whereas in the phase of transport of wood assortments the most common wound areas range from 50 to 200 cm^2.

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Sažetak

Tijekom mehanizirane sječe i privlačenja drveta nastaju oštećenja na preostalim stablima, podmlatku i zemljištu. Vrsta i veličina oštećenja koje se javljaju pri sječi, izradi i privlačenju drvnih sortimenata ovisi od broja stabala u sastojini, gustoće pomlatka, intenziteta sječe, promjera stabla, veličine krošnje, smjera obaranja stabala, nagiba terena, metoda izrade drvnih sortimenata, uvježbanosti rukovatelja, ali i od gustoće primarne i sekundarne mreže puteva. Cilj ovoga rada je utvrđivanje broja i veličine oštećenja na preostalim stablima i podmlatku u čistoj sastojini bukve i mješovitoj sastojini bukve, jele i smreke, kada se primjenjuje poludeblovna metoda. Uz to, cilj rada je i rangiranje oštećenja prema učestalosti nastanka tijekom sječe stabala i transporta drvnih sortimenata.

Istraživanja su vršena tijekom 2009. godine u čistoj sastojini bukve i mješovitoj sastojini bukve, jele i smreke na području općine Čajniče, Republika Srpska (Slika 1), na dvije pokusne površine. Sječa i izrada sortimenata izvršena je motornom pilom. Primijenjena je poludeblovna metoda izrade drvnih sortimenata i grupni način rada. Privlačenje dijelova debala i debljih grana obavljeno je traktorom Timberjack 240C po zemlji do traktorske vlake i po vlaci do kamionskog puta gdje se nalazilo privremeno stovarište.

S obzirom na broj oštećenja na preostalim stablima u sastojini, uočeno je da su oštećenja na krošnjama susjednih stabala na obje pokusne površine najučestaliji način oštećenja (Slika 2). U mješovitim sastojinama evidentirano je 169 oštećenja (0,75 po jednom stablu), a u čistim 77 oštećenja (0,77 po jednom stablu). Najmanje oštećenja tijekom sječe stabala javilo se na žilištu stabala. Na PP 1 ovaj način oštećenja uočen je na samo tri stabla (0,01 oštećenje po stablu), a na PP 2 na 12 stabala (0,12 oštećenja po stablu).

Tijekom privlačenja drvnih sortimenata do vlake, najučestalija oštećenja bila su na žilištu (Slika 2). U mješovitoj sastojini evidentirano je 48 stabala koja su imala ovo oštećenje (0,32 oštećenja po zahvatu vitla), a u čistoj sastojini 27 stabala (0,24 oštećenja po zahvatu vitla). Oštećenja na deblu i krošnji nisu zabilježena, dok su oštećenja na pomlatku vrlo izražena. Pri privlačenju sortimenata pozicioniranih paralelno s izohipsama najčešće dolazi do okretanja sortimenata oko svoje osi, što uglavnom uzrokuju ozljede na preostalim stablima i podmlatku (Slika 5).

Tijekom vuče drvnih sortimenata po vlaci do stovarišta na kamionskom putu, najčešći oblik oštećenja bio je na deblima. Ukupan broj oštećenja na deblima u mješovitoj sastojini iznosi 116, odnosno, 12 % od ukupnog broja stabala koja su se nalazila uz vlaku bilo je oštećeno na ovaj način. Oštećenja na podmlatku evidentna su kako pri sječi, tako i u tijeku skupljanja i privlačenja (Slika 2). U svakom slučaju, zbog veće gustine pomlatka u mješovitoj sastojini i broj oštećenja po srušenom stablu, odnosno po zahvatu vitla, znatno je veći nego u čistoj sastojini.

Pri sječi stabala u mješovitoj i čistoj sastojini najviše su zastupljena oštećenja čija je površina veća od 200 cm^2, a pri skupljanju i privlačenju drvnih sortimenata oštećenja veličine od 50 do 200 cm^2 (Slika 3).

KLJUČNE RIJEČI: oštećenje, mješovite i čiste sastojine, bukva, zglobni traktor, sječa i izrada, privlačenje.