Damages of Skidder and Animal Logging to Forest Soils and Natural Regeneration

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Abstract – Nacrtak

Extracting logs from stump to landings causes extensive damages to forest stand and soil. In this research two parcels adjacent to each other were selected in order to assess the effect of traditional and mechanized methods of logging on regeneration and soil compaction. A skid trail and a mule trail with similar longitudinal slope, skidding direction and total volume of extracted wood were chosen in the parcels. The cylindrical sampling method was used to determine wet and dry soil bulk density and the samples were taken at 0–10 cm and 10–20 cm depth from skid and mule trails. The results showed that soil dry bulk density increase in skid and mule trails compared to control at 0–10 and 10–20 cm depth, was significant (p<0.01). This increase in mule trail at 0–10 cm depth was significantly higher than at 10–20 cm depth (p<0.01), but percentage of soil dry bulk density increase compared to control in skid trail at 0–10 cm and 10–20 cm depths was not significantly different. Soil dry bulk density increase compared to control at 0–10 cm depth of mule trail is higher than skid trail, but at 10–20 cm depth the skid trail is higher than mule trail. Systematic random sampling method was used to determine damages to different regeneration groups due to logging operations. The results showed that damages to each regeneration group seedling and small sapling in mule logging method were significantly lower than mechanized logging method.

Keywords: animal logging, mechanized logging, natural regeneration damage, soil compaction

1. Introduction – *Uvod*

Transporting logs from stump to landings is one of the most costly and difficult operation phases of forest harvesting. The main impact of logging in forest stand are disturbances of the soil surface, change in soil physical and chemical properties, damage to natural regeneration and residual stand. Skidder traffic causes soil compaction in skid trail and because of this the soil water infiltration and aeration decrease and run off erosion increases (Croke et al. 1999, Grigal 2000, Hamza and Andersson 2005, Buckley et al. 2003, Defossez and Richard 2002, Pinard et al. 2000, Johns et al. 1996).

Skid trails, winching areas and landings are generally exposed to soil compaction during logging operations (Bob 2002).The choice of technology and performing operations under suitable terrain and weather condition are most important means of reducing harvesting disturbances on forest stand (Modry and Hubeny 2003).

Ground based skidding system using cable skidders are the only available facilities for mechanized extraction in northern Iran, because it costs less than other mechanized logging systems and is adaptable to all logging methods such as tree length and cut to length methods. On the other hand mule logging system is used to harvest steep terrains without available forest roads (Ghaffariyan 2003).

With regards to this, animal logging systems with low undesirable effects are used especially in single selection systems and areas with low road density. Wang (1997) analyzed and compared skidder and animal wood extraction systems in terms of operation cost, disturbances to soil, remaining trees and regeneration in China and reported that animal logging was more effective in the steep terrain harvesting. Rummer et al. (2001) in their study in mountainous forests of Alabama in USA showed that animal logging systems were more economical than mechanized logging systems in harvesting small area, with low stock volume and single selection system.

Williamson and Neilson (2000) measured the amount of compaction due to skidder traffic in skid trails at 10 cm depth of soil. They concluded that after first pass of machinery the amount of soil bulk density increase was 62% compared to control. Shaw and Carter (2002) showed that the change of soil physical properties during logging was a function of number of passes, soil properties and soil moisture content capacity. They used cylinder with 20 cm length and 5 cm diameter for measuring soil compaction. They concluded that soil bulk density at 0–20 cm depth increased compared to control after logging operations. The results of the study carried out by Modry and Hubeny (2003) on the impact of skidder and high-lead system logging on forest soils and advanced regeneration in Czech Republic showed that the skidder had more disturbances effects on regeneration and soil properties than high-lead system.

Makineci et al. (2008) in evaluating the effects of wood extraction on soil at 0–5 and 5–10 cm depths showed that soil dry bulk density increases in skid trails compared to control were significantly high. Eric (2006) in evaluating soil compaction at 5, 10 and 20 cm depths also concluded that the amount of soil dry bulk density compared to control was significantly high. Comparing the effect of machines of different weights on soil compaction Kim (2000) showed that soil compaction can occur at 30 cm to 60 cm depth.

Hoseini (2002) evaluated ground skidding logging and cable logging systems in Sari northern Iran and showed that the amount of damages to remaining trees and soil were higher in ground skidding logging system than cable logging system. However cable logging systems are not in use anymore, because of high costs of assembling and impossibility to provide adequately trained personnel, and in recent years single selection cutting is used in Iran and cable logging is not feasible.

Ghaffariyan (2003) studied the effect of skidding by mule on forest soil of Khairoudkenar Forest, Northern Iran, and concluded that bulk density increase in skid trails after 28 passes was 13.8%. The results of research carried out by Jamshidi (2005) in Sari Forest, Northern Iran, showed that the average bulk density of the soil under skidder traffic was significantly higher than control. While the above average values of bulk density for the skid trails were not significant.

Naghdi et al. (2007) analyzed the changes of soil bulk density and relative soil compaction for different number of wheeled skidder passes from stump to landing for two soil types (clay soil with high and low liquid limits). The findings of their research showed that the effect of skidder traffic on increasing soil bulk density at sample locations was significant.

In planning forest harvesting in Northern Iran, the only methods used in single selection cutting are the mechanized logging system with the use of cable skidder and traditional logging system using mule for extracting wood. The last case studies in Northern Iran separately evaluated soil ad stand damages by mule and tractor logging in different areas. However this study compares both extraction systems in a unit area to give the logging planners a real evaluation of site damages caused by both logging systems.

2. Materials and methods – *Materijali i metode*

This research was carried out on parcels 923 and 927 of the ninth district of Shafaroud Forest (37°22' to 37°25' N, 48°30' to 48°72' E) in Northern Iran with average altitude of 1250 m above sea level. The slopes of the parcels were 30% to 60%. Parcels 923 and 927 are adjacent to each other with 85 and 94 hectares, respectively. The trees were felled using manual chain saw and log extraction from stump to forest road side landing in traditional logging system (animal power) and ground skidding logging system (mechanized logging) were carried out by mule and Timberjack C450 wheeled skidder, respectively. Traditional and mechanized logging methods were used in parcels 923 and 927, respectively. The forest type was beach forest (*Fagus orientalis* Lipsky) with the average growing stock of 430 cubic meters per hectare.

In this research the amount of damages to different regeneration groups due to mechanized and traditional logging systems were assessed after wood extraction in the form of logs and lumber. The volume of harvested wood in the form of lumber and logs in parcels 923 and 927 were 510 m^3 and 590 m^3, respectively. Parcel 923 had a mule trail of 1000 m long, where the first 200 m started from road side landing towards the west of the parcel and branched into two 400 m trails towards the south of the parcel. Parcel 927 had seven skid trails, which could be crossed by the skidder and the longest skid trail was 600 m.

In this research systematic random sampling method was used to assess the amount of damages to natural regeneration due to logging operations (felling and extraction) in the studied parcels. The sample plots area was 100 m^2 and in order to get an appropriate distribution of sample plots a grid cells was set in 100 m by 100 m.

In order to determine the amount of natural regeneration and assess the amount of damages to it, each plot was evaluated in three stages (before felling, after felling and after extraction). Trees with diameter of less than 7.5 cm are measured as regeneration and three-growth stages are used for measuring them:

⇒ Seedling, from start of growth to 0.5 m height,

⇒ Small sapling, growth stage from 0.5 to 2 m height,

⇒ Large sapling, growth stage more than 2 m height.

Also damages to regeneration (seedling, small sapling and large sapling) are qualitatively evaluated in three degrees of bending, wounding and broken, and complete uprooting.

Two independent samples were used, *t* test and Mann–Whitney *u*-test, to show if there was a significant difference between the amount of damages to regeneration in the traditional and mechanized method of logging.

In order to study soil compaction due to log extraction in traditional and mechanized logging methods, in each of the studied parcels one skidding trail was chosen with 200 m long downward skidding, with no lateral slope and with the same average longitudinal slope (24%). These trails were assessed after extracting 100 m^3 of wood. An undisturbed area was chosen as control next to these trails.

The cylindrical sampling method was used to determine wet and dry soil bulk density; the cylinder soil sampler used was a 5cmdiameter and 10 cm height. The samples were taken at 20 m interval along trails on tire truck and mule foot step at 0–10 cm and 10–20 cm depths. Therefore in each skid and mule trail 20 samples were taken. Also 20 samples were taken along the control of each skid and mule trail at the same distance and depth. Therefore a total of 80 samples were taken for measuring soil bulk density. The formula below was used for measuring wet bulk density:

$$\gamma_w = \frac{w}{v}, \ (\mathrm{g/cm^3}) \qquad (1)$$

where:

γ_w wet bulk density

w sample weight

v cylinder volume

In order to determine dry bulk density, 100 gram of soil sample was used to measure the soil moisture content and from formula (2) the dry bulk density of the samples is determined.

$$\gamma_d = \frac{\gamma_w}{1+\omega\%}, \ (\mathrm{g/cm^3}) \qquad (2)$$

where:

γ_d dry bulk density

γ_w wet bulk density

ω% percentage of moisture content

To determine soil physical properties, 80 samples were taken at 20 m interval from sample locations and control. The boreholes were 20 cm depth and 30 cm diameter. The soil texture for each sample was determined, too.

Statistical package for social sciences (SPSS) were used for data analysis and Dunken test and least significant difference (LSD) were used for comparing averages.

3. Results and discussion – *Rezultati s diskusijom*

The total plots for assessing regeneration in parels 923 and 927 were 68 and 94 plots for traditional and mechanized logging methods, respectively. Reeneration conditions (trees with diameter less than 7.7 m) were evaluated in the above plots before felling and the total regeneration and different regeneration group dispersion were determined in the studied parcels. The average number of regeneration per hectare in parcels 923 and 927 were 3050 and 3350, respectively. The assessment of the studied parcels after felling and extraction showed that 31 and 42 plots were damaged in parcels 923 (traditional logging) and 927 (mechanized logging), respectively.

3.1 Damages to regeneration due to felling *Oštećenja naraštaja zbog sječe stabala*

The analysis of the collected data from damaged plots after felling showed that the amount of damages to regeneration in traditional and mechanized logging methods were 15.5 and 12.8%, respectively (Table 1). Comparison of total damaged regeneration after felling in the studied parcels were not significantly different ($t_{58,0.05} = 0.05$, $p = 0.96$).

Table 1 The number and percentage of regeneration damage after felling
Tablica 1. *Broj i udio oštećenja naraštaja nakon sječe stabala*

Parcel – *Odjel*	1	2
Total number of regeneration *Ukupni broj pomlatka*	879	1215
Number of damaged regeneration *Broj oštećenoga pomlataka*	136	156
Percentage *Postotak*	15.5%	12.8%

3.2 Damages to regeneration due to wood extraction – *Oštećenja naraštaja zbog privlačenja drva*

The results of analyzed data from damaged plots after wood extraction showed that the amount of damages to regeneration (seedling, small sapling and large sapling) in traditional logging method and mechanized logging method were 13.3 and 23.3%, respectively (Table 2).

The *t* test comparison of number of damaged regeneration after wood extraction showed that damages to total regeneration in traditional logging method were significantly lower than mechanized logging method ($t_{71,\,0.05} = 4.3$, $p > 0.001$).

Assessing the amount of damages to different groups of regeneration after wood extraction showed that damages to each regeneration group seedling and small sapling in traditional logging method were significantly lower than mechanized logging method (for seedling $t_{71,\,0.05} = 2.01$, $p > 0.05$ and for small sapling $z = -2.3$, $p > 0.05$). With this respect, the damages to large sapling were not significantly different in the two methods of logging ($z=-1.3$, $p=0.19$). Analyzing type of damages to different groups of regeneration due to extraction in mechanized logging showed that the number of broken seedling, small sapling and large sapling were more than bending and complete uprooting (Fig 1).

Table 2 Number and percentage of regeneration damage after wood extraction

Tablica 2. *Broj i udio oštećenja naraštaja nakon privlačenja drva*

Timber extraction *Privlačenja drva*	Mules *Mule*	Skidders *Skideri*
Total number of regeneration *Ukupni broj naraštaja*	745	1210
Number of damaged regeneration *Broj oštećenoga naraštaja*	99	281
Percentage *Postotak*	13.3%	23.3%

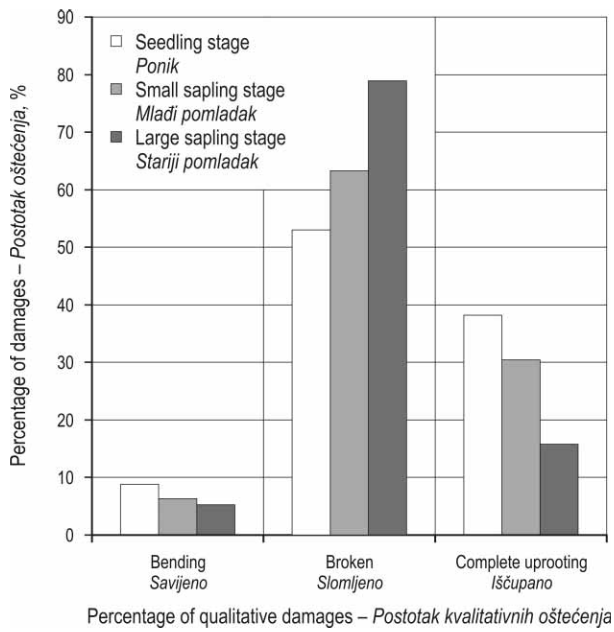

Fig. 1 Type of regeneration damage due to extraction in mechanized logging method

Slika 1. *Vrste oštećenja pomlatka zbog privlačenja drva skiderima*

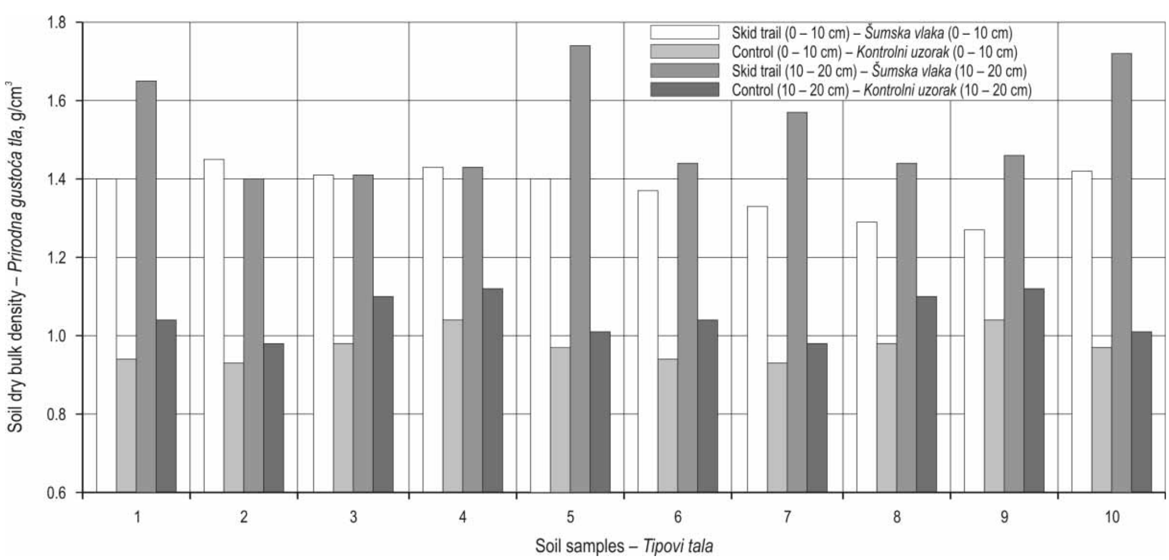

Fig. 2 Soil dry bulk density of skid trail compared to control

Slika 2. *Usporedba prirodne gustoće tla na šumskim vlakama i kontrolnim uzorcima*

3.3 Soil compaction – *Zbijanje tla*

The hydrometer test results showed that the soil texture was silt loam for all samples. In this research parameters such as moisture content, soil dry bulk density and soil dry bulk density increase (%) compared to control were measured and compared in order to determine the amount of soil damages for skid and mule trails from samples. Table 3 shows average figures for each parameter.

The results presented in Fig. 2 and Table 3 show that soil dry bulk density changes in skid trail compared to control at 0–10 and 10–20 cm depths were significantly higher ($t_{18,0.01} = -17.5$ and $t_{18,0.01} = -10.5$, $p > 0.01$).

Fig. 3 and Table 3 show soil dry bulk density changes of mule trail compared to control at 0–10 and 10–20 cm depths. In all samples of mule trail, the soil dry bulk density was significantly higher than control ($t_{18,\ 0.01} = -10.3$ and $t_{18,\ 0.01} = -7.4$, $p > 0.01$).The results show that soil dry bulk density at 0–10 cm is higher than 10–20 cm depth ($t_{18,\ 0.01} = 1.8$, $p > 0.01$) (Table 4). This demonstrates that transporting with mule affects the first depth of soil more than the second depth.

Table 3 Soil compaction in the studied trails for mule and tractor logging (with 100 m^3 volume of extracted wood)

Tablica 3. *Zbijanje tla istraživanih vlaka pri privlačenju drva mulama i skiderima (100 m^3 privučenoga drva)*

Trail *Vlaka*	Average soil dry bulk density *Srednja prirodna gustoća tla*		Percentage of soil dry bulk density increase compared to control *Postotno povećanje prirodne gustoće tla u odnosu na kontrolni uzorak*		Average moisture content *Srednja vlažnost tla*	
	g/cm^3				%	
	Depth 10 cm *Dubina 10 cm*	Depth 20 cm *Dubina 20 cm*	Depth 10 cm *Dubina 10 cm*	Depth 20 cm *Dubina 20 cm*	Depth 10 cm *Dubina 10 cm*	Depth 20 cm *Dubina 20 cm*
Mule trail control *Kontrolna animalna vlaka*	0.82	0.97			24.61	24.85
Mule trail *Animalna vlaka*	1.41	1.35	38.66	22.12	25.82	25.35
Skid trail control *Kontrolna traktorska vlaka*	0.97	1.05			24.84	21.42
Skid trail *Traktorska vlaka*	1.47	1.62	29.25	30.61	26.70	19.92

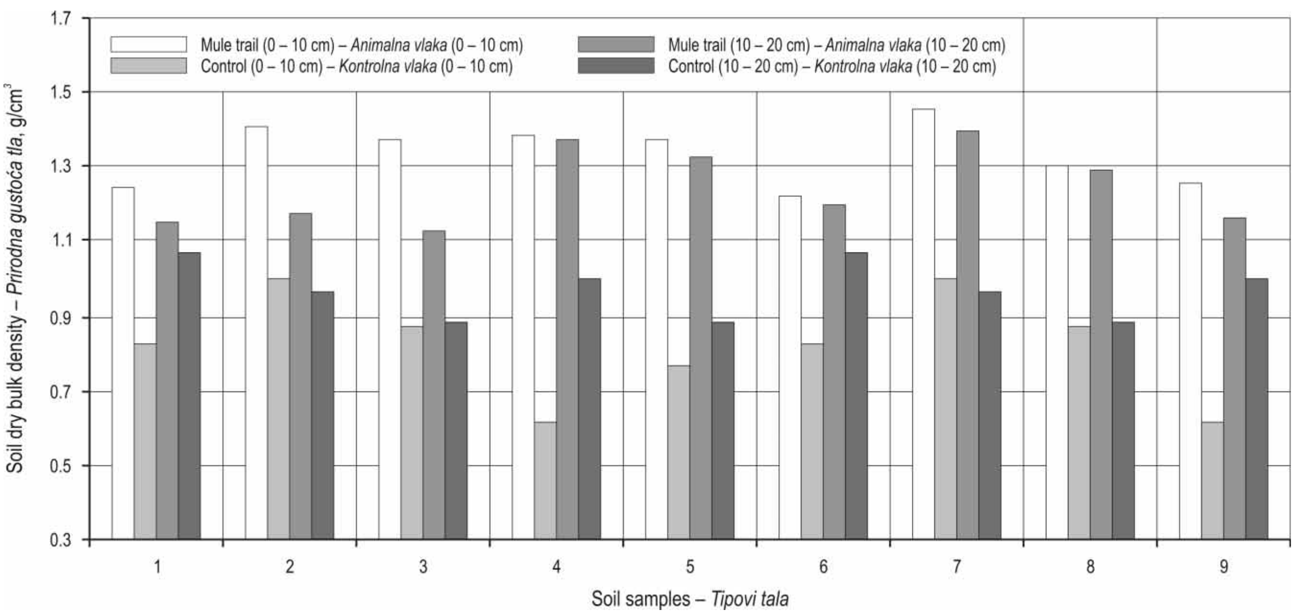

Fig 3 Soil dry bulk density of mule trail compared to control

Slika 3. *Usporedba prirodne gustoće tla na animalnoj vlaci i kontrolnom uzorku*

Table 4 Comparison of soil dry bulk density between skid trail and mule trail
Tablica 4. *Usporedba prirodne gustoće tla traktorskih i animalnih vlaka*

Trail *Vlaka*	*t value* *t vrijednost*	*Degree of freedom* *Stupnjevi slobode*	*F value* *F vrijednost*	Significance *Značajnost*
Control mule trail – Mule trail (0–10 cm) *Kontrolna animalna vlaka – Animalna vlaka* (0 – 10 cm)	–10.297	18	1.054	Significant *Značajno*
Control skid trail – Skid trail (0–10cm) *Kontrolna traktorska vlaka – Traktorska vlaka* (0 – 10 cm)	–17.470	18	2.284	Significant *Značajno*
Mule trail first depth – Mule trail second depth (0–10 cm) *Animalna vlaka, prvi prolaz – Animalna vlaka, drugi prolaz* (0 – 10 cm)	1.814	18	1.692	Significant *Značajno*
Skid trail first depth – Skid trail second depth *Traktorska vlaka, prvi prolaz – Traktorska vlaka, drugi prolaz*	–3.227	18	11.214	Non significant *Bez značajnosti*
Control mule trail – Mule trail (10–20cm) *Kontrolna animalna vlaka – Animalna vlaka* (10 – 20 cm)	–7.386	18	4.168	Significant *Značajno*
Control skid trail – Skid trail (10–20cm) *Kontrolna traktorska vlaka – Traktorska vlaka* (10 – 20 cm)	–10.458	18	13.243	Significant *Značajno*

The results of Dunken test confirmed that there were significant differences in percentage of dry bulk density increase compared to control of mule and skid trails at two depths with 100 m^3 of extracted wood for both methods (Table 5).

Percentage of soil dry bulk density increase compared to control at 0–10 cm depth of mule trail is higher than skid trail, but percentage of soil dry bulk density increase compared to control at 10–20 cm depth of skid trail is higher than mule trail ($t_{18,\,0.05} = 2.9$ and $t_{18,\,0.05} = –2.2$, $p > 0.05$) (Table 6). Soil compaction was significantly different in mule trail at two depths ($t_{18,\,0.01} = 4.05$, $p > 0.01$) and the amount of compaction at 0–10 cm depth is much higher than 10–20 cm depth. Therefore mule logging has the highest affect on surface soil depth (0–10 cm), but in skid trail the two depths were not significantly different (Table 6).

3.4 Discussion – *Rasprava*

In this research, measuring damages to different regeneration groups after wood extraction showed that in both traditional and mechanized methods of logging, the damages to seedlings were less than small and large saplings, Hoseini (1994) and Ahmadi (1996) have showed the same results. Also damages to all groups of regeneration in mule logging were significantly lower than in tractor logging. Wang (1997) and Rummer et al. (2001) in their research in mountainous forest and selective silviculture method came to the same results. In our case study the reason that the damage to regeneration is higher with mechanized method than with traditional method is because the skid trails are planned and constructed after the felling phase. Therefore, directional felling towards trails is not possible and damages to regenera-

Table 5 Results of analysis of variance between percentages of soil dry bulk density increase compared to control in traditional and mechanized methods at two depths
Tablica 5. *Analiza varijance postotnoga povećanja prirodne gustoće tla vlaka pri privlačenju drva mulama i skiderima te usporedba s kontolnim uzorcima na dvjema dubinama*

Source of variable *Izvor varijablnosti*	Soil dry bulk density increase compared to control, % *Povećanje prirodne gustoće tla u odnosu na kontrolni uzorak, %*	*Degree of freedom* *Stupnjevi slobode*	Means square *Sredina kvadrata*	*F value* *F vrijednost*
Among groups *Između grupa*	1293.310	3	431.103	Significant – *Značajno* 6.415
Inside groups *Unutar grupa*	2419.313	36	67.203	
Total *Ukupno*	3712.623	39		

Table 6 Comparison of percentage of soil dry bulk density increase between mule and skid trails (*t* test)
Tablica 6. *Usporedba postotnoga povećanja prirodne gustoće tla vlaka pri privlačenju drva mulama i skiderima (t-test)*

Trail *Vlaka*	t value *t vrijednost*	Degree of freedom *Stupnjevi slobode*	F value *F vrijednost*	Significance *Značajnost*
Mule trail – skid trail (0–10 cm) *Animalna vlaka – traktorska vlaka* (0 – 10 cm)	2.878	18	3.433	Respectively *significant* *Vrlo značajno*
Mule trail – skid trail (0–20 cm) *Animalna vlaka – traktorska vlaka* (0 – 20 cm)	–2.182	18	0.224	Significant *Značajno*
Mule trail (First depth with second) *Animalna vlaka (Prvi prolaz s drugim prolazom)*	4.048	18	0.118	Respectively significant *Vrlo značajno*
Skid trail (First depth with second) *Traktorska vlaka (Prvi prolaz s drugim prolazom)*	–0.451	18	5.479	Non significant *Bez značajnosti*

tion increases during winching logs. The results of this study showed that the type of damage to regeneration groups is mostly broken and complete uprooting and Modry and Hubeny (2003) showed similar results.

The results of this research showed that the amount of soil dry bulk density increase in skidder and mule trails compared to control at 0–10 and 10–20 cm depths, was significant. This increase in mule trail at 0–10 cm depth was significantly higher than at 10–20 cm depth. Soil dry bulk density increase in skid trails at 0–10 and 10–20 cm depths was not significantly different.

The comparison of percentage of soil dry bulk density increase in skid and mule trails for 100 m^3 of wood extraction at 0–10 cm and 10–20 cm depths showed that this increase was significantly different. This increase at 0–10 cm depth for mule trail was higher than for skid trail. The results of study carried out by Toms (1996) showed that animal skidding causes more compaction of soil surface. McGonagil (1979) concluded that horse skidding causes more compaction of soil surface than subsoil. With the same amount of wood extraction volume (100 m^3), mule logging has more passes (traffic) than the skidder, and therefore causes more compaction of soil surface.

Comparison of soil dry bulk density increase at 10–20 cm depth for mule and skid trails showed that this increase in skid trail was higher than in mule trail. Although the number of skidder passes was lower, the weight of the loaded skidder caused depth soil compaction. The soil moisture content at 10–20 cm depth was nearer to optimum soil moisture content and maximum compaction occured at this moisture content.

4. Conclusions – *Zaključci*

This study showed that damages to natural regeneration due to logging in traditional method was lower than in mechanized method, but the soil compaction of surface soil (0–10 cm depth) by animal logging was higher than by tractor logging. Therefore regeneration establishment would be difficult. In this study the skid trails were planned after felling, which caused more damages to soil and forest stand. Planning skid trail before felling phase could be applied with directional felling to avoid high stand damages.

This study compared both extraction systems in a unit area to give the logging planners a real evaluation of site damages caused by both logging systems. The results of this research can be useful as environmental criteria for future researches to evaluate current logging systems in hilly terrains and to choose the best alternative and develop a decision support system for logging planning in this area.

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Sažetak

Štete na tlu i pomlatku pri privlačenju drva skiderima i animalnom vučom

Privlačenje drvnih sortimenata od panja do pomoćnoga stovarišta uzrokuje velika oštećenja u šumskoj sastojini i na tlu, što se očituje u promjenama fizičkih i kemijskih svojstava tla te oštećenjima na pomlatku. Istraživanje je provedeno u dvama susjednim šumskim predjelima u sjevernom Iranu. Cilj je istraživanja bio ocjena posljedica radova pridobivanja drva na obnovu sastojine i zbijanje tla pri privlačenju drva mulama i skiderima Timberjack C450. Privlačenje drva skiderima s vitlom uglavnom se primjenjuje u sjevernom Iranu zbog manjih troškova od drugih sustava privlačenja i zbog toga što je takav sustav pogodan za privlačenje pri svim metodama sječe i izradbe. Animalno privlačenje drva uglavnom se koristi u prorednim sastojinama i na područjima s malom otvorenošću šuma.

Na istraživanim šumskim predjelima odabrane su šumske vlake sa sličnim uzdužnim nagibom, smjerom privlačenja i ukupnim obujmom privučenoga drva. Sjeklo se motornom pilom u sastojini orijentalne bukve (Fagus orientalis Lipsky) s prosječnom drvnom zalihom od 430 m^3/ha. Oštećenost biljaka u različitim razvojnim stadijima *utvrđena je prije i nakon sječe i izradbe te nakon privlačenja drva. Za procjenu oštećenja primijenjena je metoda planskoga nasumičnoga uzorka površine 100 m^2 u mreži kvadrata 100 × 100 m.*

Radi određivanja zbijenosti tla zbog privlačenja drva mulama i skiderima na svakom istraživanom šumskom predjelu izabrane su vlake duljine 200 m sa smjerom privlačenja nizbrdo, prosječnim uzdužnim nagibom od 24 % i bez poprečnoga nagiba na izabranim vlakama. Za određivanje prirodne gustoće tla korištena je metoda uzimanja uzoraka pomoću valjaka. Uzorci su uzimani na dvjema dubinama tla, od 0 do 10 cm i od 10 do 20 cm na traktorskoj i na animalnoj vlaci nakon 100 m^3 privučenoga drva.

Rezultati pokazuju da su oštećenja na naraštaju značajno niža pri privlačenju drva mulama nego pri privlačenju skiderima (tablice 1 i 2). Što se tiče zbijenosti tla, rezultati pokazuju da postoji značajna razlika u prirodnoj gustoći tla, koja je veća na svim vlakama u odnosu na kontrolne uzorke koji su uzimani pored vlaka na istim dubinama. Povećanje je na animalnoj vlaci značajno veće na dubini od 0 do 10 cm nego na dubini od 10 do 20 cm, ali postotak povećanja prirodne gustoće tla u usporedbi s uzorkom na traktorskoj vlaci na objema dubinama ne razlikuje se značajno. Povećanje prirodne gustoće suhoga tla na dubini od 0 do 10 cm s obzirom na kontrolni uzorak veće je na animalnoj vlaci, ali na dubini od 10 do 20 cm to je povećanje veće na traktorskoj vlaci.

Ovo je istraživanje pokazalo da su oštećenja u prirodno obnovljenoj mladoj sastojini manja pri privlačenju drva mulama, ali je zbijenost tla na dubini od 0 do 10 cm veća nego pri privlačenju drva skiderima. Također u ovom istraživanju šumske su vlake bile projektirane nakon sječe, što se pokazalo loše jer su nastale velike štete na tlu i u šumskoj sastojini. Da bi se izbjegla velika oštećenja sastojine, uz projektiranje šumskih vlaka prije sječe trebalo bi primijeniti i usmjereno obaranje stabala. Rezultati ovoga istraživanja mogu biti primjenjivi kao okolišni kriterij u budućim istraživanjima pri vrednovanju trenutačnoga sustava i odabira najboljega načina privlačenja drva u brdskim područjima.

Ključne riječi: animalno privlačenje, privlačenje skiderima, oštećenje naraštaja, zbijanje tla

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Received (*Primljeno*): July 12, 2008
Accepted (*Prihvaćeno*): November 20, 2009