Mule Logging in Northern Forests of Iran: A Study of Productivity, Cost and Damage to Soil and Seedlings

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Abstract – Nacrtak

Animal logging is one of the traditional logging systems in Iran, as in many other areas of the world. In this study, after determination of the work elements, a continuous time study method was used to develop hauling time prediction models for wood hauling by mule for firewood hauling with standard saddles, firewood hauling with special equipment, and pulpwood hauling. The elemental time prediction models are also presented in this paper.

The firewood production outputs in billet hauling were 2.135 m^3/h using standard saddles, and 3.275 m^3/h using special equipment. Pulpwood hauling productivity was 1.246 m^3/h. The contract costs for hauling firewood and pulpwood were 1.02 €/m^3 and 1.28 €/m^3, respectively. Soil disturbance was observed on 5.72% of the harvesting area, and the soil compaction in the studied skid trail increased by 14.14%.

Keywords: animal logging, production, wood hauling model, load volume, soil compaction, disturbed area

1. Introduction – *Uvod*

Animal logging is still the traditional forest harvesting system in many areas of the world. Around 300 million draught animals such as oxen, horses, mules, elephants and lamas are in use around the world. Animal logging is used in the U.S.A, Chile, Brazil, Egypt and most of near east countries (FAO 1987). As in machine based harvesting, selecting the optimal animal logging method and pattern as well as limiting site and residual stand damage from logging are key elements of an effective and economical harvesting operation. Study of animal logging production and site impacts can provide baseline information that can be used for selecting specific and optimized animal logging methods. There are numerous published studies of animal logging operations.

Mule skidding in Alabama was studied in pine and broad-leaf timber stands with slopes of 0 to 6%. In uphill skidding, the average skidding distance was about 125 m and the mean diameter of trees was 30 cm. The work team included 8 workers and 3 mules and the production was 17.172 m^3/h (McGonagil 1979). The results showed a low level damage to skid trails. Approximately 5 cm of the upper soil was disturbed and some of trees were damaged. The most important damage to the residual trees included broken branches by tree felling (McGonagil 1979).

L. Wang studied animal logging and ground skidding machines in the Mountain Region of Heilongjiang in China (Wang 1997). The load volume ranged from 0.2 to 0.6 m^3, the harvesting volume ranged from 20 to 60 m^3/ha and slope varied from 15% to 27%. Skidding distance was the most important factor influencing skidding costs, which varied from 500 to 2000 m. The result indicated that machine skidding caused higher soil disturbance but was more economical for long skidding distances (more than 1769 m).

Toms studied animal logging in Alabama as a small scale harvesting system (Toms et al. 1996). The production rate ranged from 2.45 m^3/h to 3.13 m^3/h, for two skidding teams and one cutter. Mean daily production was 16,095 m^3 and mean payload was 0.212 m^3. Felling and skidding costs were 20.89 US $ per m^3.

Residual stand damage in selective cutting by two skidding systems including mule logging and machine skidding was studied in the Ozark Mountains of Missouri. The percentage of the logging unit occupied by skid trails was 1% in the mule logging units and 4.6% in the skidder units (Ficklin et al. 1997).

A study of »wood extraction with oxen and agriculture tractors« was carried out by E. Rodriguez in Chile. Skidding models were developed for two slope classes, –6% to –15% and –16% to –25% and for two classes of wood products, sawlogs and pulpwood. The skidding distance ranged from 20 to 240 meters (FAO 1987). Spinelli and Baldini (1987) reported that mule and horse are still common in logging operation in Italy. They pointed that mule hauling takes over from modern machinery in the terrains steeper than 40–50% and rocky soils when the small quality of the wood does not allow the economical use of cable crane. The lack of forest road and lower capital cost are another reason to use mules for logging coppice forests. They found that uphill hauling is more time consuming than downhill. Akay (2008) also studied the skidding operation with ox for sawlog and pulpwood.

Logging damages to the residual timber stand caused by skidders, tractors and mule logging were studied by Ahmadi (2000) in the forests of Northern Iran (in Lavidj as a part of Amol). Approximately 27.1% of the residual stand was damaged by mule logging.

Mule logging stand damage was studied in Rouyan forests. In this study, 5.14% of seedlings were grazed, 4.2% of saplings were curved, 7.4% of sapling stems were wounded, and 4.2% of seedlings and yearlings were destroyed (Tashakori 1996).

In Iran mule logging was used for many years for hauling firewood, pulpwood and sawlogs. The main difference between mule logging in Iran and mule logging researched in studies in other countries is that in Iran the payloads are hauled fully suspended by the mules, rather than skidded by them. No studies have been carried out on cost, productivity or soil or stand damage cased by mule logging in Iran. Therefore it was necessary to develop productivity models for hauling firewood and pulpwood, and to determine soil properties changes and damage to seedlings caused by mule logging.

2. Study methods – *Metode istraživanja*

2.1 Sites of study – *Mjesta istraživanja*

The first study site was the Compartment 218 of Namkhaneh district in the Research and Training Forest Center of Nowshahr in the Northern Iran. The harvest area was 31.5 ha with the minimum and maximum elevation above the sea level of 1100 and 1260 meters, respectively. The general slope was 30% with western exposure and on a brown washed soil called *Fageto-Carpinetum*. The standing volume was of 441.8 m^3 per hectare (Namiranian 1997).

The second study site was conducted on Compartment 114 of the Patom district with an area of 38.4 ha and minimum and maximum elevations above sea level of 650 and 750 m. The general slope was 35% to the north with brown soil; the stand type was *Fageto-Carpinetum*. The unit had a standing volume of 324 m^3 per ha (Namiranian 1993).

2.2 Climate of study site – *Klimatska obilježja*

There was no climate data available for these forestlands, but according to the meteorology station in Nowshahr which is 10 km away from this location and based on long term period information (from 1971 to 2000), the warmest month was July with an average temperature about 24.6 °C and the coldest one was February with an average temperature of about 7.5 °C. The greatest average monthly rainfall is 237.6 mm, in October, and the lowest is 475 mm, in June.

2.3 Work organization – *Organizacija rada*

The work team included a mule, a worker for manual loading and a teamster. The pulpwood, lumber (usually their thickness, width and length are 14 cm, 28 cm and 2.28 m, respectively) or firewood are fastened with a rope to the saddle of the mule (Fig. 1). For firewood hauling, a V-shaped rack (Fig. 2) can also be used. Sometimes, two or three mules may be connected by a rope, allowing a single driver to lead more than one mule. The important point in mule logging in Iran is that firewood and pulpwood are hauled on a saddle rather than skidded. The maximum payload is about 120 kg; the mules are not as strong as horses or mules used in other countries. Mule logging is used in these four situations; firstly where there is no skid trail available for using skidders or tractors, secondly the cut volume is not so high or timber is scattered in the compartments, thirdly the logging area is too steep and use of tractors is not possible and fourthly after extracting the sawlogs by mechanized systems, firewood or pulpwood are extracted by mules (Ghaffarian 2003).

2.4 Data Collection – *Prikupljanje podataka*

A continuous time study method was used. The typical work cycle included loading the processed wood (firewood and pulpwood) on mules, hauling the loads to landings, unloading and returning.

Fig. 1 Hauling pulpwood by mules

Slika 1. *Privlačenje celuloznog drva mulama*

The hauling distance, skid trail slope and volume per load were measured.

In order to get the volume per turn for pulpwood, the length and diameter of each piece were measured. For firewood, the length and the diameters of five pieces selected at random from each load were measured, and from this the mean volume per piece of firewood was calculated. The volume per turn was estimated by multiplying the mean volume by the number of pieces per turn (which ranged from 5 to 30, depending on the piece size). No technical or personal delays were observed during the time study. For this study 55 working cycles were recorded during the two working days.

Fig. 2 Using V-shaped rack to haul firewood

Slika 2. *Upotreba V-okvira za iznošenje ogrjevnoga drva*

In order to determine the disturbed area caused by mule logging, all of the skid trails, processing sites and landings in Compartment 218 were surveyed.

In Compartment 114 before skidding, in a distinct skid trail with the length of 45 m and a width of 5 m, all of the seedlings were inventoried and classified according to height (h<30 cm, 30<h<130 cm, h>130 cm).

After the pulpwood and firewood were hauled by mules (post-hauling), seedlings in the skid trail were inventoried and evaluated again according to the above mentioned classifications. The seedlings could also be characterized by wound type such as health, wound (most parts of the stem were damaged), semi- wound (some parts of the stem and leaves were damaged), broken top (the crown of sapling was broken), crushed (the stem and the crown of saplings were completely damaged and crushed) and grazed by mules.

Both the pre- and post- hauling seedling inventories were carried out in November (autumn).

In order to determine the degree of soil compaction based on a random systematic sampling method, soil samples were collected at 5 m intervals. Ten soil samples had been used for compaction tests and 5 samples for determining pH-value changes from pre-hauling to post-hauling periods. The number of trips was 28 in the skid trail.

To determine relative compaction, dry density (g/cm^3), moisture content percentage, optimal moisture content and maximum dry density were measured in 10 soil samples. The excavation method was used for soil sampling. In the excavation method (Blake and Hartge 1986), dry soil density is determined by excavating a hole in the ground, oven-drying and weighing the amount of soil removed from the ground to determine the mass, and measuring the volume of the excavation. The volume can be determined in different ways. One is to use the sand-funnel method (ASTM 1992a) in which a selected type of sand with a known volume per unit mass is used to completely fill the hole. Then, the volume can be determined by measuring the total mass of sand needed to fill the hole. Another possible way to measure the volume is to use the rubber-balloon method (ASTM 1992b). In this technique, a balloon is placed in the hole and filled with a liquid (water) up to the hole border. The volume of the excavated soil sample is then equal to the volume of the liquid in the balloon. An advantage of using the excavation method to measure dry densities of soils other than the core method is that it is more suitable for heterogeneous soils with gravels.

The dry soil density of a sample is evaluated on the basis of two measured values: (1) M_s, the oven-dried mass of the sample and (2) V_t, the field volume or the total volume of the sample. For the calculation of soil particle density (*s*), mass (M_s) is measured after drying the sample at 110 ± 5 °C until a near constant weight is reached. This laboratory technique directly determines the dry density of a soil sample. Maximum dry density is the dry density obtained by the compaction of soil at its optimum moisture content.

The relative compaction could be calculated by using the following formula,

$$RC = \frac{\gamma_d}{\gamma_{d\max}} \cdot 100 \qquad (1)$$

Where:

RC Relative compaction, %

γ_d Dry density, g/cm^3

$\gamma_{d\max}$ Maximum dry density, g/cm^3

It should be noted that it was not possible to determine the actual soil compaction by mule logging under undisturbed forest stands because the harvesting area was not completely undisturbed.

2.5 Cost of Hauling System – *Troškovi privlačenja*

The costs of the hauling system include costs of animal purchase, hauling instruments (straps, pack-saddle, and sandal), maintenance of animals and labor costs. In this study the system costs incurred by having an animal conductor contract. Based on the contract, the proposed hauling costs for firewood and pulpwood are 1.02 €/m^3 and 1.28 €/m^3, respectively (Considering the exchange rate of 1 € = 13670 Rials of Iran).

2.6 Statistical Analysis – *Statistička obrada podataka*

The chosen model is a multiple regression to show the effects of operating variables on production as a function. The important factors related to saving time and costs like hauling distance, skid trail slope and volume per load were measured. The kind of extracted wood including firewood, firewood hauled by V-shape rack and pulpwood was also used as a dummy variable. The interaction between hauling distance and load volume as well as the interaction between hauling distance and trail slope were considered in the modeling process.

3. Results – *Rezultati*

3.1 Hauling time prediction model – *Model za procjenu vremena privlačenja*

The extraction time prediction model was developed by stepwise regression using SPSS.

$$t = 2.37 + 0.033 \cdot s - 0.00046 \cdot s \cdot i + 0.686 \cdot W \quad (R^2 = 0.83,\ n = 55) \qquad (2)$$

Where:

t Hauling time, min/cycle

s Hauling distance, m

i Slope (inclination), %

W W is a dummy variable indicating the kind of extracted wood. Its values for firewood, hauling firewood with special V shape rack and pulpwood are 1, 2 and 3, respectively.

The R-square of 0.83 indicates that the developed model explains 83% of the variable variability.

The significant level of the ANOVA table shows that the model is significant at α=0.05.

Table 1 Analysis of variance for the extraction time prediction model
Tablica 1. *Analiza varijance za model procjene vremena privlačenja*

	Sum of squares *Suma kvadrata*	Degree of freedom *Br. stupnjeva slobode*	Mean square *Varijanca*	*F*	Significance *Značajnost*
Regression *Regresija*	393.639	3	131.213	101.678	0.000
Residual *Ostatak*	65.814	51	1.290		
Total *Ukupno*	459.453	54			

Table 2 Collinearity statistics
Tablica 2. *Dijagnoza kolinearnosti*

Variable *Varijabla*	Tolerance *Tolerancija*	VIF *Faktor inflacije varijance*
Hauling distance *Duljina privlačenja*	0.732	1.366
Hauling distance × Slope *Duljina privlačenja × nagib*	0.732	1.366
Kind of wood *Vrsta drva*	0.991	1.009

Table 3 Summary statistics of variables
Tablica 3. *Statistika ispitivanih varijabli*

	Minimum *Najmanje opažanje*	Maximum *Najveće opažanje*	Mean *Aritmetička sredina*
Distance, m – *Duljina privlačenja*, m	20	267	82.19
Slope, % – *Nagib*, %	–30.00	17	-18.22
Load volume, m^3/cycle – *Obujam tovara*, m^3/*tura*	0.079	0.665	0.224
Loaded travel time, min/cycle – *Vrijeme kretanja pod teretom*, min/*tura*	0.58	4.51	1.83
Empty travel time, min/cycle – *Vrijeme kretanje bez tereta*, min/*tura*	0.59	10.52	2.52
Loading time, min/cycle – *Vrijeme utovara*, min/*tura*	0.66	3.04	1.50
Unloading time, min/cycle – *Vrijeme istovara*, min/*tura*	0.39	2.18	0.89
Cycle time, min/cycle – *Trajanje ciklusa*, min/*tura*	2.82	16.63	6.749

The variance inflation factor (VIF) and tolerance values were computed to test if there is collinearity among the variables. The VIFs values of Table 2 are not high and confirm that the collinearity is not a problem in the developed model.

The summary statistics of the variables is presented in Table 3.

3.2 Elemental time prediction models – *Modeli za procjenu osnovnih vremena*

3.2.1 Loading time prediction model – *Model za procjenu vremena utovara*

It was assumed that the loading time is a function of load volume and kind of wood (pulpwood, firewood or using V-shape rack). Using the multiple regression method, the following model was constructed.

$$t_1 = 0.417 \cdot W + 3 \cdot V \ (R^2 = 0.75, n = 55) \qquad (3)$$

Where:

- t_1 Loading time, min/cycle
- W Kind of wood
- V Load volume, m^3/cycle

3.2.2 Unloading time prediction model – *Model za procjenu vremena istovara*

To develop this model, loading time was used as a function of load volume, kind of wood and the interaction of these variables using multiple regression.

$$t_2 = 0.184 + 0.35 \cdot W + 0.658 \cdot V \ (R_2 = 0.44, n = 55) \qquad (4)$$

Where:

- t_2 Unloading time, min/cycle
- W Kind of wood
- V Load volume, m^3/cycle

3.2.3 Loaded travel time prediction model – *Model za procjenu vremena opterećenoga kretanja*

The variables such as hauling distance, slope of skid trail and load volume were used in modeling.

$$t_3 = 0.016 \cdot s + 1.322 \cdot V - 0.006 \cdot i \ (R^2 = 0.96, n = 55) \qquad (5)$$

Where:

- t_3 Loaded travel time, min/cycle
- s Hauling distance, m
- V Load volume, m^3/cycle
- i Slope (inclination), %

3.2.4 Empty travel time prediction model – *Model za procjenu vremena neopterećenoga kretanja*

It was assumed that the time of empty travel in mule logging depends on hauling distance and trail slope.

$$t_4 = 0.027 \cdot s - 0.029 \cdot \mathrm{i} \ (R_2 = 0.9, n = 55) \qquad (6)$$

Where:

- t_4 Empty travel time, min/cycle
- s Hauling distance, m
- i Slope (inclination), %

Table 4 presents production and cost rates depending on kind of extracted wood in mule logging operation of this case study. The average production rate and hauling cost are 1.99 m^3/h and 1.05 €/m^3, respectively.

The use of special woody instrument increased the hauling productivity by 53.4%.

Table 4 Production rates of this study

Tablica 4. *Razine proizvodnosti utvrđene istraživanjima*

Wood *Vrsta drva*	Production, m^3/h *Proizvodnja, m^3/h*
Firewood – *Ogrjevno drvo*	2.135
Firewood with V-shaped rack *Ogrjevno drvo s V-okvirom*	3.275
Pulpwood – *Celulozno drvo*	1.246

3.3 Damage to Soil and Seedlings – *Oštećivanje tla i pomlatka*

All skid trail, processing sites and landings in Compartment 218 were surveyed. The surveying results of skid trails and landings are listed in Table 5.

The skid trail in Compartment 114 had the area of 239.5 m^2. Number of seedlings decreased from 546 to 377 which means that 30.95 % of seedlings was destroyed by mule logging in this skid trail.

The mean value of relative compaction was increased by 14.14% after hauling, and a two-sample t-test of the pre- and post-harvest data showed a significant increase at α=0.01. The pH-value did not change significantly after mule logging.

Table 5 Information of disturbed areas by mule logging in Compartment 218

Tablica 5. *Podaci o površinama oštećenim privlačenjem drva mulama, odjel 218*

Area of compartment, ha *Površina odjela*, ha	31.5
Total disturbed area, m^2 *Ukupno oštećena površina*, m^2	18018.12
Disturbed area, % *Oštećena površina, %*	5.72
Mean area of skid trails, m^2 *Srednja površina vlaka*, m^2	291.08
Mean area of processing site, m^2 *Srednja površina radilišta sječe i izrade*, m^2	298.9
Mean area of landings, m^2 *Srednja površina stovarišta*, m^2	291.08
Mean width of skid trails, m *Srednja širina vlaka*, m	4.58
Mean length of skid trails, m *Srednja duljina vlaka*, m	54.38

Table 6 Pre-harvest and Post-harvest regeneration results of skid trails (Compartment 114)

Tablica 6. *Rezultati obnove vlakama prije i poslije sječe (odjel 114)*

		Pre-harvest *Prije privlačenja*	Post-harvest *Poslije privlačenja*
Number of seedlings *Broj sadnica*	Class h<30 cm *Visina h<30 cm*	278	130
	Class 30<h<130 cm *Visina 30<h<130 cm*	261	242
	Class h>130 cm *Visina h>130 cm*	7	5
	Total – *Ukupno*	546	377

Table 7 Number and percentage of damaged seedlings in the skid trail in Compartment 114

Tablica 7. *Broj i udio oštećenoga pomlatka na putu privlačenja drva u odjelu 114*

Damage type *Vrsta oštećenja*	Number *Broj biljaka*	%
Crushed – *Potpuno uništene*	10	1.38
Broken top – *Slomljen vrh*	9	1.65
Semi-wound – *Lakše ranjene*	36	6.59
Wound – *Ranjene*	71	13
Grazed – *Okrznute*	15	2.75

Table 8 Soil properties of the skid trail in Compartment 114 (for 28 cycles of hauling by one mule)

Tablica 8. *Svojstva tla na putu za privlačenje drva u odjelu 114 (za 28 ciklusa privlačenja jednom mulom)*

	Pre-harvest *Prije sječe*	Post- harvest *Poslije sječe*
pH – *pH-vrijednost*	5.512	5.49
Mean of dry density, g/cm^3 *Sred. gustoća u suhom stanju*, g/cm^3	1.135	1.371
Percentage of moisture, % *Postotak vlage, %*	21	21.55
Maximum of dry density, g/cm^3 *Naj. gustoća u suhom stanju*, g/cm^3	1.61	1.62
Percentage of optimal water, % *Postotak optimalne vlage*, %	16	18
Mean of relative compaction, % *Srednja relativna zbijenost, %*	70.49	84.63

4. Conclusion – *Zaključci*

The production rate is different in pulpwood and firewood. The present instruments used for mule logging are old and inefficient for economical logging. By using a V-shaped rack the cost of hauling productivity can be increased by 53.4%. Despite the limited number of data in this study, the results suggest using more intensively suitable new animal logging instruments. In order to help minimize the costs of this system, another research should be developed on processing costs of woods so that they have suitable weight and dimensions.

These results relate to dry density soils which are strongly influenced by their soil genus and their soil moisture. For getting more general figures it is also necessary to choose different soils in other studies. It would also be wise to carry out the research aimed at comparing mechanized logging systems (ground based systems and cable systems) as well as animal logging systems based on economical and environmental issues.

Acknowledgement – *Zahvala*

The authors wish to thank Prof. Dr. Karl Stampfer from BOKU for his support in this paper.

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Sažetak

Privlačenje drva mulama u šumama sjevernoga Irana: istraživanje produktivnosti, troškova i oštećivanja tla i pomlatka

Privlačenje drva životinjama još je uvijek tradicionalni način pridobivanja drva u mnogim dijelovima svijeta. Oko 300 milijuna radnih životinja, kao što su volovi, konji, mule, slonovi i lame, koriste se širom svijeta. Animalno privlačenje drva primjenjuje se u SAD-u, Brazilu, Egiptu i većini bliskoistočnih zemalja (FAO 1987). Kao i pri

mehaniziranom pridobivanju drva, odabir odgovarajuće metode privlačenja te kontrola oštećivanja tla i sastojine ključni su elementi učinkovitoga i ekonomičnoga privlačenja drva. Istraživanja proizvodnosti animalnoga privlačenja drva i utjecaja na stanište pritom mogu pružiti osnovne informacije za odabir odgovarajućih optimalnih metoda animalnoga privlačenja drva.

U Iranu se za privlačenje ogrjevnoga i celuznoga drva te trupaca godinama koriste mule. Glavna razlika između privlačenja drva mulama u Iranu i animalnoga privlačenja drva u drugim zemljama jest što se u Iranu privlačenje gotovo u potpunosti obavlja vezivanjem i iznošenjem tovara, a ne vučom po tlu. Najveći tovari iznose oko 120 kg; mule nisu toliko snažne kao konji ili kao mule u drugim zemljama. Privlačenje mulama koristi se u četiri situacije: prvo, kada nema izvoznih putova pogodnih za zglobne šumske ili obične traktore, drugo kada sječna gustoća nije visoka ili je posječeno drvo razbacano po odjelu, treće ako je područje prestrmo i upotreba traktora nije moguća te četvrto, nakon mehaniziranoga privlačenja trupaca ogrjevno i celulozno drvo se privlači mulama (Ghaffarian 2003). Istraživanja troškova, produktivnosti i oštećivanja tla i sastojine pri takvu privlačenju drva dosada u Iranu nisu provedena. Stoga se smatralo potrebnim razviti modele za procjenu učinkovitosti privlačenja ogrjevnoga i celuloznoga drva i utvrditi promjene u svojstvima tla te štete na pomlatku uzrokovane privlačenjem drva mulama.

U provedenim istraživanjima primijenjena je metoda studija vremena. Uobičajeni je radni ciklus obuhvatio utovarivanje izrađenoga drva (ogrjev i celuloza) na mule, iznošenje tovara do stovarišta, istovar i povratak. Radna je ekipa obuhvaćala mulu, radnika za ručni utovar i vodiča. Celulozno drvo, trupci (obično debljine do 28 cm i duljine do 2,28 m) ili ogrjevno drvo užetom su vezani za sedlo mule. Za iznošenje ogrjevnoga drva korišten je okvir u obliku slova V. Jedan je vodič istodobno vodio dvije ili tri mule povezane užetom. Za svaki ciklus privlačenja drva mjereni su duljina privlačenja, nagib na putu privlačenja i obujam tovara. Tijekom dva radna dana snimljeno je 55 ciklusa privlačenja drva. Na osnovi snimljenih podataka u radu su oblikovani modeli za procjenu osnovnih vremena privlačenja, i to za privlačenje ogrjevnoga drva sa standardnim sedlom, za privlačenje ogrjevnoga drva s posebnom opremom i za privlačenje celuloznoga drva.

Istraživanja su provedena na dva lokaliteta. Prvi je lokalitet bio odjel 218 Namkhaneh okruga u Centru za istraživanje i obuku Nowshahr na sjeveru Irana. Površina je obuhvaćenoga područja bila 31,5 ha s nadmorskom visinom od 1100 do 1260 m. Prosječan nagib terena iznosio je 30 %, bio je sjeverne ekspozicije, a drvna je zaliha bukovo-grabove zajednice bila 441,8 m^3/ha (Namiranian 1997). Drugi je lokalitet bio 114. odjel okruga Patom, površine 38,4 ha i nadmorske visine između 650 i 750 metara. Nagib je iznosio oko 35 %, prema sjeveru, zajednica bukve i graba s 324 m^3/ha drvna zalihe (Namiranian 1993).

Radi utvrđivanja površine oštećenoga područja, uzrokovano privlačenjem drva, u odjelu 218 promatrani su svi putovi privlačenja, radilišta sječe i izrade drva te stovarišta. U odjelu 114 na putu za privlačenje (duljine 45 m i širine 5 m) prije privlačenja prebrojan je pomladak i mlade su biljke razvrstane u razrede prema visini (h<30 cm, 30<h<130 cm, h>130 cm). Nakon privlačenja drva ponovno je napravljena inventura i ocijenjeno stanje pomlatka. Dodatno su opisane vrste oštećenja na biljkama. Zbog utvrđivanja stupnja zbijanja tla uzeto je i analizirano 10 uzoraka tla. Pritom su mjereni gustoća u suhom stanju (gr/cm^3), postotni sadržaj vlage, optimalni sadržaj vlage i maksimalna gustoća u suhom stanju. Pet uzoraka tla prije i poslije privlačenja također je uzeto za određivanje promjena u pH-vrijednosti tla.

Istraživanjima je utvrđeno da proizvodnost na privlačenju ogrjevnoga drva iznosi 2,135 m^3/h ako se koristi standardna oprema, odnosno 3,275 m^3/h ako se za utovar ogrjevnoga drva koristi V-okvir. Proizvodnost je na privlačenju celuloznoga drva 1,246 m^3/h. Troškovi privlačenja ogrjevnoga i celuloznoga drva iznosili su 1,02 EUR/m^3 odnosno 1,28 EUR /m^3. Oštećivanje je tla utvrđeno na 5,72 % površine pridobivanja drva, a zbijenost tla na mjestu privlačenja drva povećana je za 14,14 %. pH-vrijednost tla nije se značajno promijenila nakon privlačenja. Na promatranom putu privlačenja u odjelu 114 mulama je uništeno 30,95 % od postojećega broja biljaka.

Rezultati su istraživanja pokazali da je razina proizvodnosti za celulozno i ogrjevno drvo različita. Postojeća je oprema za privlačenje mulama zastarjela i neučinkovita za ekonomično privlačenje drva. Samo primjenom V-okvira produktivnost se može povećati za 53,4 %. Iako su podaci u ovom istraživanju nedostatni, rezultati ipak upućuju na potrebu korištenja nove i bolje odgovarajuće opreme za animalno privlačenje drva. Da bismo pridonijeli smanjenju troškova takva načina rada, dodatna bi istraživanja trebala obuhvatiti ispitivanje troškova sječe i izrade drva kako bi ono bilo odgovarajućih dimenzija i težine.

Za podrobnije podatke o utjecaju na tlo i oštećivanje nužno je za istraživanja odabrati i druge vrste tala, zajednica i sastojina. Također bi bilo dobro u istraživačke planove uključiti usporedbu mehaniziranih načina pridobivanja drva (privlačenje po tlu, iznošenje žičarom) i animalnoga privlačenje drva s obzirom na ekonomsku i okolišnu prihvatljivost.

Ključne riječi: animalno privlačenje drva, proizvodnost, obujam tovara, zbijanje tla, oštećivanje sastojine

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Received (*Primljeno*): May 5, 2008
Accepted (*Prihvaćeno*): April 8, 2009