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Full Length Research Paper

Timber extraction with mules: A case study in the Hyrcanian Forest

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The Hyrcanian (Caspian) forest in northern Iran has a richness of biological diversity, with endemic and endangered species, and a diverse range of economic and social conditions. With a focus on low impact timber extraction and small scale tree harvesting, the proportion of mule logging has recently increased. The objective of this study is to assess the efficiency of mule logging operations in the Hyrcanian forests through a comprehensive time study, and further to attempt to identify opportunities for improvement. The research was carried out in the Namkhaneh district of the Kheyroud Forest. Four type mule logging crews were selected for this study, carrying either sawlog or pulpwood sized material, in either uphill or downhill directions. Mule extraction time was recorded, and independent variables expected to affect mule hauling productivity were documented. Average turn time for hauling sawlogs uphill and downhill was 8 and 8.6 min respectively. Turn time for hauling of pulpwood uphill and downhill was 8.24 and 8.06 min respectively. Approximately 20% of the total time was delay. Regression models were developed for production-related elements. Productions of lumbers hauling were more than pulpwoods. The average hourly cost of a mule hauling system in this area was $6.44 per productive mule hour. Overall, the results suggest that mule hauling operation in the Hyrcanian Forest can meet economic, silvicultural, environmental, and social objectives.

Key words: Forest operations, timber harvesting, animal logging, mule extraction, time study.

INTRODUCTION

Log extraction with draught animals continues to be an economically attractive choice in many areas, sometimes even in industrialized countries (Rodriguez and Fellow, 1986; Wang, 1997). As compared with ground-skidding equipment, the use of draught animals has been shown to reduce soil disturbance, soil compaction and damage to residual trees significantly (Ghaffarian, 2002; McCabe and Tiner, 1992; Rodriguez and Fellow, 1986; Shrestha et al., 2005; Wang, 1997). Direct impacts are generally limited to the narrow skidding paths used by the animals. Animal skidding can be particularly advantageous for thinning or pulpwood harvesting, where relatively small logs are to be extracted or where products from pit sawing or other onsite processing are to be transported. While lack of capital is one reason for the popularity of animal hauling in many developing countries, another reason is the need to meet local environmental constraints. Heinrich (1985) identified three levels of harvesting operations: 1) labor-intensive, 2) intermediate-technology, and 3) fully mechanized. Logging with animals is considered to be labor-intensive. In cases where forestry machines have low cost efficiency and terrain conditions are favorable, animals can provide a successful solution. Oskarshamn (1983) stated that worldwide 400 million draught animals were utilized for transportation and agriculture of which horses and mules comprised 37 million. Only a fraction of this horses and mules total are used in logging operation.

In different regions of the world, various species of animal have been used such as oxen, donkeys, horses, elephants, lamas, yaks, and mules. Among these animals, ox is commonly used in skidding operations because it is very strong and easy to drive. Rodriguez and Fellow (1986) studies oxen logging in plantation and natural forests and

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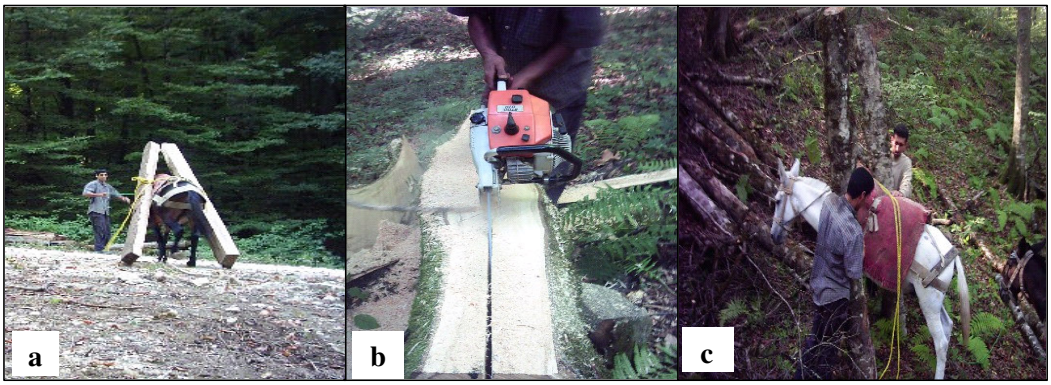

Figure 1. (a) Mule hauling lumber along the forest road, (b) forest worker using a chainsaw to process a tree into lumber in the forest, and (c) hooking pulpwood onto the mule in the stand.

his results suggest they can be successfully used in thinning and clear cut, as well as on level and steep ground. Additionally, it provides a good yield in beef at the end of its active life, so the investment can be recovered. Thompson and Sturos (1984) mentioned that horses could skid through tight spaces in partial cuts, with very little damage to residual boles. Oskarshamn (1983) reported that skidding with horses is suitable for a distance of 25 to 100 m with skidding tongs, 50 to 300 m with sled-type equipment and skidding bogies, and 100 to 1,000 m with wagons. Horses are suitable for winter weather because they can tolerate cold weather, whereas mules can work better than horses in hot weather (Shrestha et al., 2005). McCabe and Tiner (1992) recommended that mule logging be carried out on small acreages with selective cutting where landowners want minimum damage to the remaining trees and areas not accessible to skidders.

A number of case studies of animal logging have been published. Eisenhauer (1969) studied skidding with oxen and they achieved an average productivity of 1.62 m^3/h (radiata pine, 32 cm DBH, 11% slope, 125 m average skidding distance, log lengths between 3 and 7 m). Ghaffarian (2002) studied the production and cost of mule logging in Kheyroud Forest, showing productivity in billet hauling was 2.1 m^3/h, billets hauling with special equipment 3.3 m^3/h and pulpwood hauling 1.25 m^3/h. The Hyrcanian (Capsian) Forest in northern Iran has a richness of biological diversity, with endemic and endangered species, and a diverse range of economic and social conditions. Most of the animal logging in Hyrcanian Forest regard it as family tradition that logging operators learned from their fathers. Animal logging in northern Iran is typically comprised of a crew of five or six people and seven or eight mules. Trees to be removed are felled, limbed and topped motor-manually. Felled trees are processed with chainsaws into lumber and or pulpwood (Figure 1). The dimensions of lumber were 2.2 to 2.8 m in length, 30 to 34 cm width and 10 to 15 cm thickness. These dimensions apply because this is the mule maximum tolerable hauling weight (Sarikhani, 2000).

This traditional mule hauling system was established in Hyrcanian Forest because the forest management plan and the forest road network were undeveloped. Recently, with increasing of environmental interest, concentration on environmentally sound timber extraction and small scale tree harvesting, the proportion of mule logging was increased in Caspian Forest. Published information about utilization, cost and productivity is very limited for animal logging. This study focused on increasing the body of knowledge about this traditional method of logging employing animals for timber extraction. The objective of this study is to carry out a comprehensive time study to improve the utilization of mule logging operations. It will also improve the quality of hauling cost and productivity information available for use in forest management plans and decisions.

MATERIALS AND METHODS

Study area

The research was carried out in compartment No. 213 of Namkhaneh Forest Management Unit, Kheyroud Educational and Research Forest Station. The altitude range was between 850 and 950 m above the sea level and the forest lies on an eastern aspect. Average rainfall ranges from 1420 to 1530 mm/year, with the heaviest precipitation in the summer and fall. Temperatures are moderate, ranging from a few degrees below 0°C in December, January, and February to +25°C during the summer.

The forest stand was unevenly aged and its main type was fagetum with average growing stock of 456 m^3/ha. Soils have developed from cretaceous rock and are deep heavy clays with weak drainage and high hydromorphology. The silvicultural regime is selection based and the harvests were done as group-selection and single-tree selection.

Cycle time elements

The basic cycle time used for this study was a single mule haul turn time; that is, from the time the mule leaves the landing until it returns with the wood, unloaded at the landings and is ready to leave again.

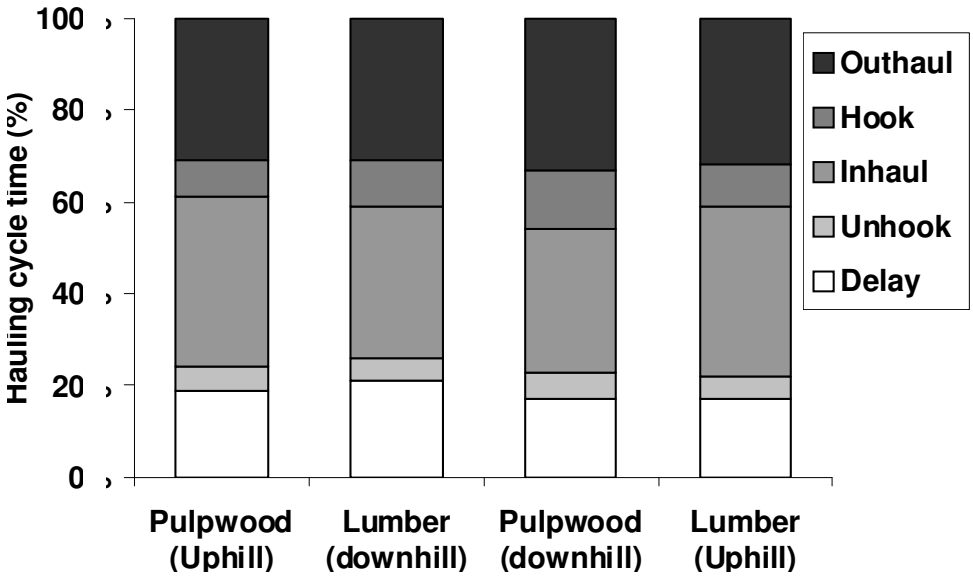

Figure 2. Distribution elemental times per mule hauling.

The elements that make up the cycle are outhaul, inhaul, hook, and unhook. Similar extraction phases have been used in many studies. The four different cycle time elements are as follows:

i) Outhaul time: Travel time of the unloaded mule from the time it leaves the landing until it arrives at the stump area.
ii) Hook time: Time spent from the moment the mule arrives at the stump until it leaves. This includes maneuvering the mule, arranging the load on to the mule and tying them off.
iii) Inhaul time: Travel time of the loaded mule from the moment the mule starts to move with the lumbers or pulpwood from the stump until it arrives at the landing.
iv) Unhook time: Time spent from the moment mule arrives the landing to deliver the load until it leaves the landing again. This includes untying the load, unloading and stacking of the lumber or logs.

In addition to these productive elements there is a single delay category as well. Any time during the study that was not spent in one of the four productive time elements was categorized as delay.

Data collection

Field data were collected during July and August, 2004. The combination of timber type and topography limits mechanization to the transport function. Felling, limbing, topping, and processing of trees are motor manual. Mules are used on the more gentle slopes. Four mule logging crews working in Kheyroud Forest were selected for this study. To study the difference between uphill and downhill hauling, and to study the differences in hauling pulpwood versus sawn lumber, four separate studies were carried out:

1) lumber hauling in downhill;
2) lumber hauling in uphill;
3) pulpwood hauling in downhill; and
4) pulpwood hauling in uphill.

The logging crews used in this study all had at least 15 years experience in logging with mule and can therefore be considered very experienced. Mule logging crew, individual operators, and animals were independent variables.

In addition to measuring the mule hauling cycle time with a deci-minute stop watch, independent variables expected to affect mule hauling productivity were documented. Hauling distance (meters), slope of hauling trail (%), number of pieces in a load, and total volume of the load were documented for each turn. In order to determine the required number of cycles, 15 cycle of hauling were time studied prior to the main study for variance of hauling cycle without delay. Finally, 24 and 27 samples were selected for hauling of lumber in uphill and downhill respectively. 26 and 29 mule cycles were studied for hauling of pulpwood in uphill and downhill respectively.

RESULTS

The time study data was compiled and analyzed for basic trends. The distribution of elemental times per mule hauling lumber and pulpwood cycle are shown in Figure 2. Average total cycle time for hauling lumber in downhill and uphill are 8 and 8.6 min, respectively. The average cycle time for hauling of pulpwood downhill and uphill are 8.24 and 8.06 min respectively. Approximately 20% of the total study time was delay. Table 1 shows the statistics summary of time study variables for mule extraction.

Figure 3 shows the total cycle time for the pulpwood extraction relative the extraction variable haul distance. Similarly, Figure 4 shows the total cycle time for the lumber extraction relative the extraction variable haul distance.

As expected, cycle time is strongly influenced by haul distance for these operations. However, compared to other published studies, a very high percentage of the cycle time variation is explained by the variable haul distance alone. Figures 5 and 6 shows that hauling cycle time of lumber and pulpwood in the uphill configuration increases as the volume per turn increases. While there is also a trend

Table 1. Statistics summary of time study variables for mule extraction.

Factor	Crew	Mean		Standard dev.		Minimum		Maximum	
		uphill	downhill	uphill	downhill	uphill	downhill	uphill	downhill
Delay time (min)	Lumber	1.83	2.15	1.6	1.7	0	0	4.76	5.76
	Pulpwood	1.85	1.66	1.3	1.61	0	0	4.09	5.83
Delay free time (min)	Lumber	8.6	8	3.4	4.05	2.96	2.95	14.7	15.7
	Pulpwood	8.06	8.24	3.8	4.43	2	3.01	14.67	16.08
Total time (min)	Lumber	10.4	10.15	4.23	4.22	3.11	3.06	17.25	17.24
	Pulpwood	9.91	9.89	4.21	4.43	2.04	3.37	17.41	18.38
Extraction distance (m)	Lumber	197.4	169.9	84.9	103.3	36	31.3	342	352.9
	Pulpwood	193.4	174.9	87.7	105.35	36	33.6	345	353
Slope of trail (%)	Lumber	14.1	-18.9	7.2	7.77	3.5	-29.5	28	-5
	Pulpwood	15.2	-18.81	7.5	7.61	3.51	-29.1	28	-5
Volume per load (m^3)	Lumber	0.17	0.2	0.05	0.04	0.09	0.14	0.26	0.29
	Pulpwood	.15	0.15	.04	0.04	.08	.08	.22	0.22
Number of pieces	Lumber	2	2	0	0	2	2	2	2
	Pulpwood	3	2.6	1.3	1.04	2	2	6	6

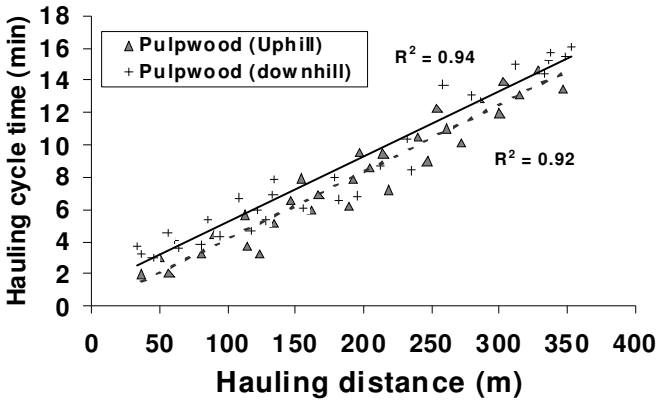

Figure 3. Relation between time of hauling pulpwood and hauling distance (m).

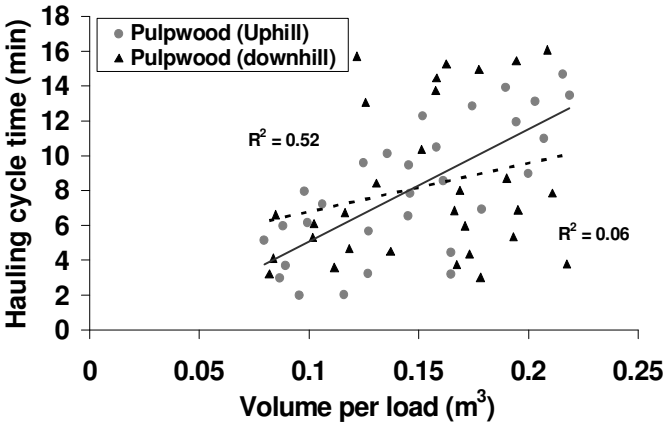

Figure 5. Relation between pulpwood hauling time and volume per turn (m^3).

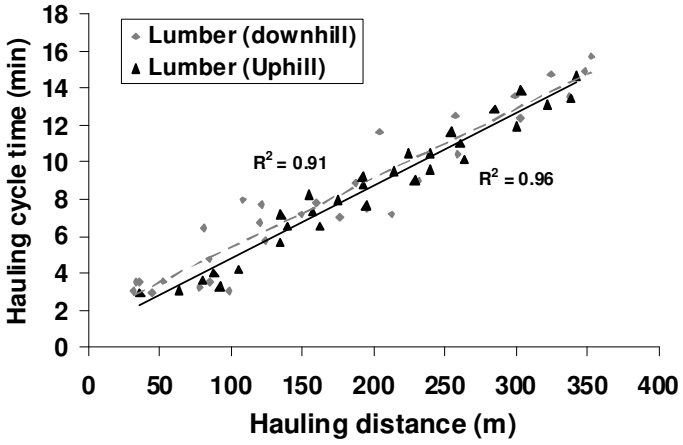

Figure 4. Relation between time of lumber hauling and hauling distance (m).

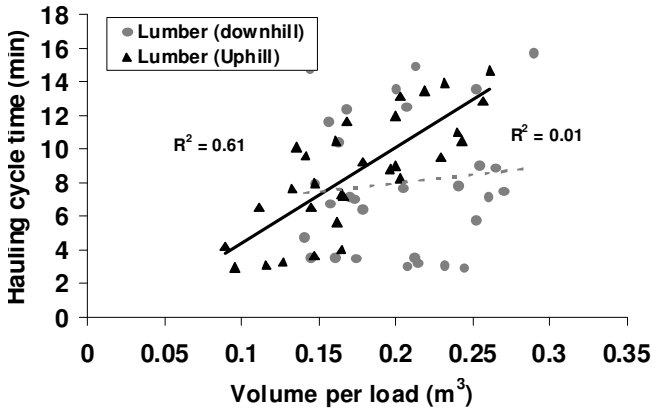

Figure 6. Relation between lumber hauling time and volume per turn (m^3).

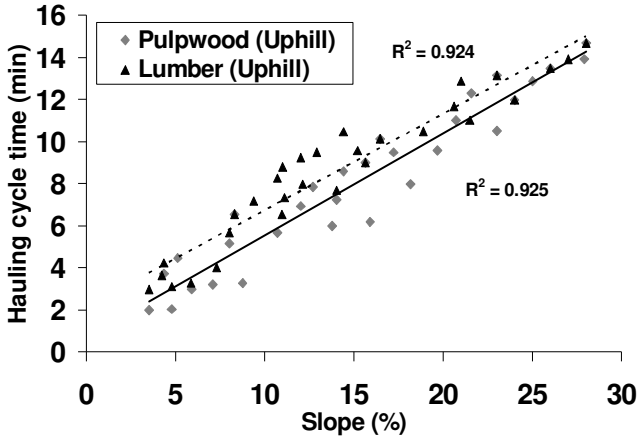

Figure 7. Relation between uphill hauling time and hauling trail slope (%).

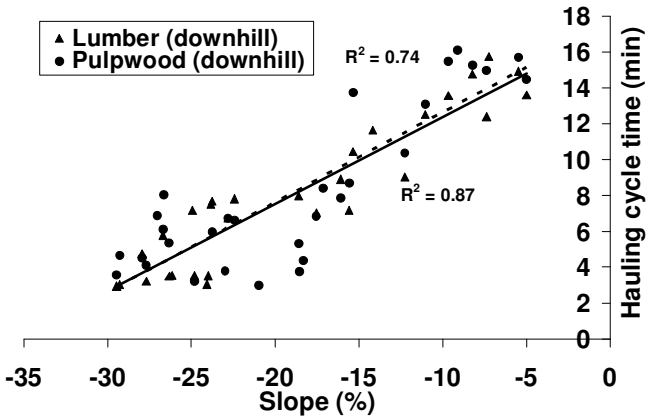

Figure 8. Relation between downhill hauling time and hauling trail slope (%).

showing this to be true for downhill extraction, this effect is not significant.

A possible compounding reason for this correlation of increasing load and total cycle time is that the workers make sure that the load is maximized when the mules have to travel the longest distance.

Figures 7 and 8 show that hauling cycle time of lumber and pulpwood in uphill increases as the degree of slope increases.

The statistical program SPSS 14.0 was used to create cycle time models based on stepwise regression. The independent variables included hauling distances (D), hauling trail slope (S), volume per turn in cubic meters (V) and number of pieces in a single load (N). Compound variable were also included in the regression. The dependent variable is total cycle time without delay (T). The time equations calculated for the mule are presented in Table 2.

Where in Table 2:

T= hauling cycle time without delay (min); D= hauling distance (m); V= volume per turn (m^3); S= slope of hauling trails (%).

From equations in Table 2, hauling distance has a more effect on hauling cycle time for hauling of pulpwood and lumber in different slopes.

Production of mule hauling system

The production of hauling with mule (cubic meter per hour) can be obtained by using the production and time data as follows:

Unit production = TP / TT (1)

Where:

TP = total volume of hauling wood to landing (m^3); TT = total hauling time (h)

The hourly production of hauling with mule (m^3/h) with delay time, for hauling of lumber in uphill and downhill were 1.001 and 1.2 m^3/h respectively, while for hauling of pulpwood in uphill and downhill it was 0.88 and 0.89 m^3/h respectively (Figure 9).

Hourly productions of lumbers hauling were more than pulpwoods. Results showed that production of lumber in down slope was greater than production of lumber in uphill. There was no significant difference between production of pulpwood hauling in down and up slope. Figure 10 shows that production of hauling pulpwood and lumber in down and up slopes decreases sharply as the distance increases, the critical point being at about 200 m.

Animal rate

The animal rate is usually divided into three main cost components including fixed, operating and labor cost. Mules can be productive to the age of 35 years and their useful life is between six and seven years. Useful mule hauling work hours were 5 h per day.

Fixed cost

Fixed cost components include the investment cost of the mule ($1333), mule saddle (pack) and other equipments with twice replacement in year (111 $/year), logging ropes with monthly replacement (267 $/year), mule shoes cost with 30 replacements in year (117 $/year). Mules support

Table 2. Time equations (regression models) per working cycle in hauling lumber and pulpwood with mule.

Type of logs	General slope of trail	Regression models	n	R^2
Lumber	Downhill	T= 4.88 + 0.0306 D + 0.55 S×V	27	0.93
Lumber	Uphill	T= - 0.22 + 0.035 D + 10.741 V	24	0.96
Pulpwood	Downhill	T= 2.13 + 0.0431 D + 0.00055 D×S	29	0.95
Pulpwood	Uphill	T= 0.061 + 0.022 D + 0.25 S	26	0.96

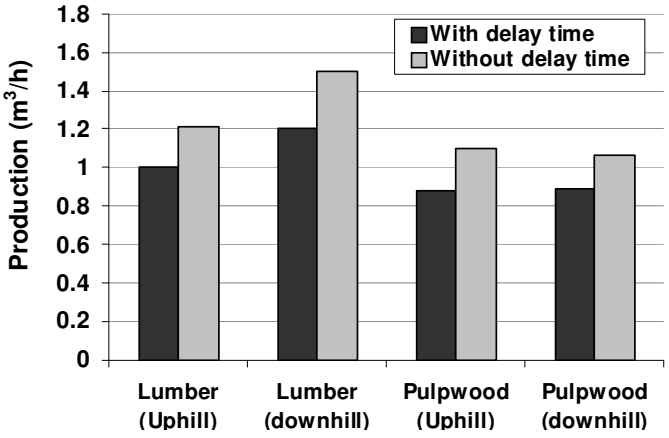

Figure 9. Hourly production (m^3/h) of mule hauling with and without delay time.

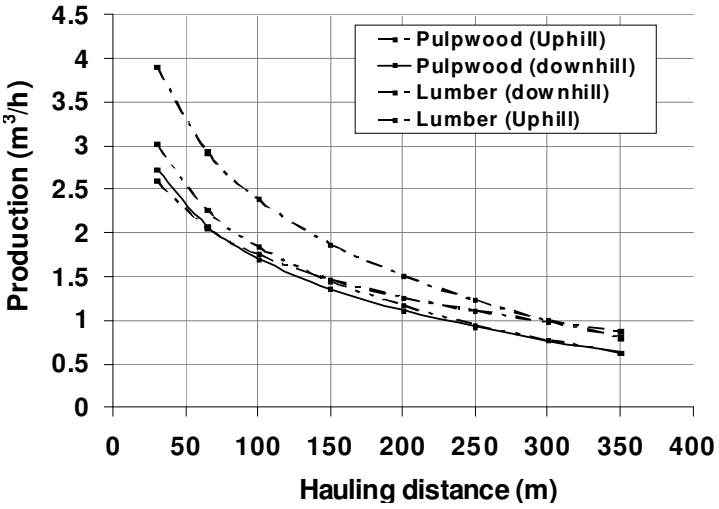

Figure 10. Hourly production (m^3/h) of mule hauling with hauling distance (m).

costs, which include pasture rental, food supplements, veterinarian services, and any after hours care-feeding, washing or guarding, do not vary with working hours (1622 $/year). The money invested in medical attention, medicine and vaccination can be considered to be five percent of the purchase value of a mule was 67 $/year.

Operating cost

Operating cost components generally include maintenance and repair costs for saddles, ropes, and miscellaneous equipment. Additional or special feed given to mules during hauling may also include operating costs at 111 $/year.

Labor cost

Labor cost is the driver's cost for driving the animal during the hauling operation. It only includes the wage of a workman that was $1.1 per day. In addition, mule rate or hourly cost of mule hauling system in productive mule hour was $6.44.

Mule hauling cost

The unit cost of hauling with mule per cubic meter can be obtained by using the production and cost data as follows:

Unit cost = C / P(3)

Where:

C = mule rate for hauling ($/h); P = production rate (m^3 /h)

The unit cost of hauling with mule ($/$m^3$) with delay time, for hauling of lumber in uphill and downhill were 6.43 and 5.37 $/$m^3$, respectively and for hauling of pulpwood in uphill and downhill were 7.32 and 7.24 $/$m^3$, respectively (Figure 11).

The hauling cost of lumber is less than the cost of pulpwood hauling, because the condition of hauling for pulpwood was different. The load might consist of 2 to 6 bolts which were so closely stacked that when the rope was fastened it was though they were only one or two lumber. Managing and control of delay time can be decreased the hauling cost. Investigation on the effects of hauling distances on the time of doing work for mule in downhill and uphill of lumber and pulpwood hauling and as a consequence, the changes of hauling costs, shows that increasing hauling distances variable on both log types caused to linear increase in cost (Figure 12).

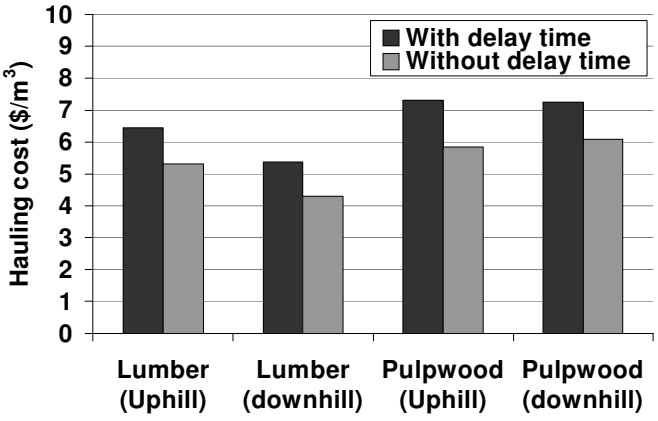

Figure 11. Hourly cost ($/m^3) of mule hauling with and without delay.

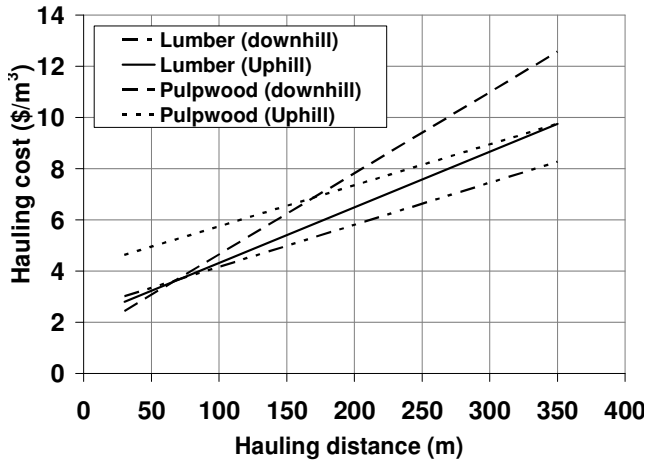

Figure 12. Variation hourly cost ($/m^3) of mule hauling with hauling distance (m).

Table 3. Cost equations per m^3 in hauling lumber and pulpwood with mule.

Type of logs	General slope of trail	Cost equation
Lumber	Downhill	C= 22755+147.53 D
Lumber	Uphill	C= 19315+195.41 D
Pulpwood	Downhill	C= 13427+284.89 D
Pulpwood	Uphill	C= 37381+144.02 D

Table 3 gives the cost equation per m^3 for hauling lumber and pulpwood over different types of slope.

Where in this Tab 2:

C= hauling cost ($)

D= hauling distance (m)

DISCUSSION AND CONCLUSION

This traditional system was established in Caspian Forest in a few past decades but the productivity and utilization of this system was undeveloped. In addition to develop a method of data collection to improve the efficiency of mule logging operations, this study improves the quality of hauling cost and productivity.

Hourly productions of lumbers hauling were more than pulpwoods. The result showed that production of lumber in down slope was greater than production of lumber in uphill. As Wang (1997) mentioned, from equations in table 1, hauling distance has a more effect on hauling cycle time for hauling of pulpwood and lumber in different slopes. The output of mules in down slopes was less than up slopes. It should be pointed out that in hauling lumbers, speed of movement and volume tend to be greater than in hauling pulpwood; and output is higher because more time is spent in loading of pulpwoods. The hauling cost of lumber is less than the cost of pulpwood hauling, for pulpwood the situation was different. The load might consist of 2 to 6 bolts which were so closely stacked such that when the rope was fastened it was as though they were only one or two lumber. It was found that there was no difference in production between hauling of pulpwood in downhill with uphill hauling. The result showed that production of mule hauling in this study was lower than that of Ghafarian (2002) since the hauling distance in this study was longer. Oskarshamn (1983) reported that skidding with horses was suitable for a distance of 25 to 100 m with skidding tongs; but in this research, hauling with mule was suitable for a distance of 30 to 250 m in downhill slope and 30 to 150 m in uphill slopes.

Basically, mule operations for extracting log in Hyrcanian Forest have a difference with animal logging in other parts of the world. Lumber, pulpwood and fuelwood set on the back of mules and wood do not touch the ground or has the least touch, since the mule haules the load to the landing; but other animals skid the logs and pulpwood on ground with suitable equipments such as skidding tongs, sled-type equipment and skidding bogies, wagons. Mules move in a narrow path and have a low disturbance on soil surface and stand damage. According to the data from Kheyroud Forest (Jourgholami, 2004), the production of both mule hauling and machine skidding are shown in Figure 13. As a comparison, the mule production rate is 10 to 15% of Timberjack wheeled skidder, but it should be noted that the production cost of mule hauling system is less than skidder by approximately 60 to 70%.

Hyrcanian Forests, model of broad-leaved forests primary pattern after post-classical period in northern hemisphere. This forest has distinct floristic, ecologic, wildlife characteristics and is the exclusive site for some rare Iranian species. About 40% of the Hyrcanian Forests

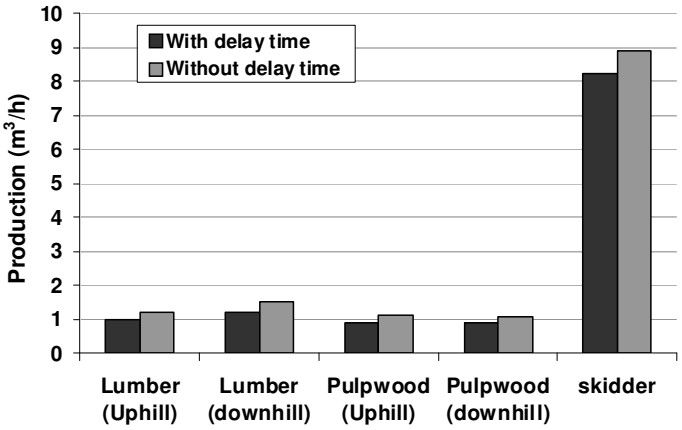

Figure 13. Comparison of production between mule hauling and timberjack wheeled skidder.

are located in mountainous areas, where forest lands are not accessible with ground-based logging equipments and cable yarding technologies undeveloped in this forest. So, mule logging can provide a solution to accessibility in this critical mountainous terrain. The results of evaluation test or practices indicated that this timber extracting technique are feasible, applicable and reasonable in small tree harvesting with a relatively low impact to environment and a moderate operation cost. The wages paid to forest workers in the North of Iran are low and mule logging was extremely laborious; therefore mule logging is suitable for solving employment problems. Mule hauling operation in Hyrcanian virgin forest and protected forest area can meet economic, silvicultural, environmental and social objectives.

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