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Comparison of the production performance of rubber-tired skidder in three different sites according to sea level height (low height, middle height, high height)

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Abstract

Advice from forest machines performance under different site conditions can be the base of accurate scheduling and increasing of machine usage. Skidder Timberjack 450c is most common machines in northern forests of Iran. Three different forest sites in low height, middle height and high height were selected to compare the hourly production performance of this skidder. The elements of skidding cycle was determined and then 48, 40 and 55 skidding cycle was studied using continues time study method. After data analysis the mathematical model was obtained to predict the skidding time in each site. This model in low height was the function of skidding distance, route slope, volume and number of timber. In middle height was the function of skidding distance, volume and number of timber and in high height was the function of skidding distance, route slope, winching length and slope. The mean number of timber decreased from low height to high height in each cycle and the mean volume of timber increased. The hourly production (with calculation of pure time) was 6.57 m^3/h in low height, 8.42 m^3/h in middle height and 9.57 m^3/h in high height. The hourly production of this skidder in different sites with different elevation at sea level was significantly different

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Introduction

Forest extraction is indispensable activity (Rizvandi & Jourgholami, 2012). The hardest step in extracting wood from forest is the primary transportation, in which the wood is transferred from stump to depot and from economical aspect the maximum production cost of timber belongs to this step. There are several transportation methods that ground skidding is the commonest one (Wasterlund, 1994). Parallel to the development of the machinery, it is necessary to examine the performance of the institutions involved in the forestry industry, which plays an important role in the level of machine performance optimization and economic planning of the operation (Davis & Kellogg, 2005). Skidder Timberjack 450C after two decades is still the most popular machine for extracting log projects in northern Iran. Differences between species and consequently differences between the given logs may influence the quality of hourly production rate of skidder through changing volume of the load. The most important factor in productivity of forest and differences in species is the altitude from sea level (Hasanzad *et al.*, 2004). Also Razavi (2009) on his research in the Noor region of northern Iran showed that the effect of altitude from sea level in the average cutting surface is significant. Based on a classification, different heights of forests in northern Iran are divided to: low height (less than 700 m), middle height (200-700 m), and high height (above 2000 m) (Saeed, 1995). So the operation of skidder in extracting log varies in these regions.

Sabo & Porsinsky (2005) in studying the performance of skidder Timberjack 240D in spruce and beech forests of Croatia, calculated the function of machine in skidding distances of 50 and 400 m, respectively 16.9 and 9.9 m^3/h. Barari (2011) in his study evaluated hourly production rate of wheeled skidder HSM 904 low height forest of northern Iran for 525 meters distance of skidding without delay equal to 8.7m^3/h. Lotfalian *et al.*, (2011) in their study on Timber jack 450C in the low height forests of northern Iran, with 980 meters skidding distance, calculated the net daily production 20.199 m^3/h. According to Çalışkan (2012) research in the jungles around Black Sea in Turkey the function of skidder (MB Trac 900) in terms of production without delay time was estimated at 11m^3/h. The purpose of the research is the accurate evaluation of hourly production rate performance of skidder Timberjack 450C with the assumption that in different habitats hourly rate of production varies in terms of altitude from sea level.

Materials and methods

This study is done in the forests under the management of Nekachoob Company in Neka region in North of Iran three high restricts with the following characteristics:

Table 1. Characteristics of the study areas.

Characteristics	Low height	Middle height	High height
Parcel number	101	233	422
Altitude (m. a. s. l.)	200	800	2000
Average slope (percent)	25	30	35
General direction	Northern	Southern	Northern
Forest type	Oak-hornbeam	Beech-Hornbeam	Beech–Hornbeam
Silvicultural system	Selection cutting	Selection cutting	Selection cutting
Skidding way	Downhill	Downhill	Downhill

Identical conditions in the study areas are necessary to perform such study. So we had tried to put the influential factors of control in the same conditions. Implementation of forest practices in the study areas were single-mode method and the direction of skidding in all parcels were downward. It was tried to make the extent, shape and size of depots similar on three areas because shape, extent and slope of depots play an important role in the performance of Skidder (Lotfalian, 2011). For the calculation of the machine performance, Work Study method was used. Work Study is a term that encompasses study techniques, methods and timing. At first skidding cycle, is divided into specific elements including: traveling empty toward the forest from depot, staying in an appropriate place, hooking cable to the logs, travelling loaded out of forest toward depot, unhooking the cable and piling the logs in depot.

For time study, continuous time method was used. This method is common in forest engineering works (Mc Donald & Fulton, 2005). In each high region, the number of samples required in every area was calculated with formula 1 (Zobeyri, 2000).

$$n = \frac{t^2 \times (Sx\%)^2}{(E\%)^2} \quad (1)$$

n = number of samples
t = student coefficient
S = standard deviation
E = the desired accuracy

Timing operation was done and simultaneously other required information including: measuring distances of skidding, lengths of winching (with a tape), the slope of skidding path (with a sounto) and logs volume per cycle with formula (2), were recorded.

$$V = \frac{\pi}{4} \times d^2 \times h \quad (2)$$

d= middle diameter of logs
h =length of log

It is necessary to explain that the data was recorded for skidding distances less than 1000 meters. SPSS17 software and stepwise regression method by mathematical model determined the prediction of net skidding time. Skidder hourly rate of production per area is calculated using formula 3.

$$P = \frac{V}{T} \quad (3)$$

P = production rate (m^3/h)

V = volume of extracted wood (m^3)

T = required time to extract wood (hour)

To compare the hourly production rate of skidder in three study areas, accounting net skidding time per cycle in each region, the hourly rate of production was calculated and compared using statistical comparison.

Results

Calculated samples and measured statistical parameters 'characteristics in three study areas are shown in Tables 3, 4 and 5.

Mathematical model to predict skidding time in each region was determined using stepwise multiple regressions.

(4) Low height: $Y=505.3+2.05 D_g +1.5 S_g +19.6V+29.7N$

(5) Middle height: $Y=435.07+2.71D_g +89.7V+132.4N$

(6) High height: $Y=46.62+1.8 D_g +16.65 D_w +16.3 S_g +19.7 S_W$

S_g= skidding distance slope
N= number of logs
D_g= skidding distance
V= load volume

In order to verify the validity of model, two periods of timing information were extracted randomly from timing data which were not involved in making models, and they were compared with the estimated time of model and the estimated confidence limits namely upper and lower limits. And an observation of each model is recorded in table 2. Comparison shows that the models are valid.

Table 2. Validation of regression models.

	Skidding time	Estimate time	Confidence limit
Low height	1079	1216	1110<1216<1440
Middle height	1258	1460	1210<1460<1642
High height	775	815	662<815<1148

Skidding distance variable in all three areas, volume variable, number of loads in low height and high height, and skidding distance slope variable in low height and high height were involved in the model.. In high height area winching distance variable and winching slope, as influencing variables, were involved in the model.

Table 3. Calculated statistical parameters of measured variables in low height.

Variable	Total skidding time (second)	Net skidding time (second)	Skidding distance (m)	Winching distance (m)	Winching slope (%)	Number of logs	Load volume (m^3)	Skid way slope (%)
Average	1456	1340	365	11.56	4.44	1.92	2.44	11.56
Minimum	642	642	100	2	0	1	0.99	2
Maximum	3254	2024	745	25	9	4	6.28	25
St. Deviation	492.5	352.5	143.1	3.8	2.7	0.98	1.12	3.8

Table 4. Calculated statistical parameters of measured variables in middle height.

Variable	Total skidding time (second)	Net skidding time (second)	Skidding distance (m)	Winching distance (m)	Winching slope (%)	Number of logs	Load volume (m^3)	Skid way slope (%)
Average	1440	1361	353	22.6	3.25	1.9	3.17	11.08
Minimum	580	580	120	8	0	1	1.8	7
Maximum	2355	2175	525	40	8	4	4.7	16
St. Deviation	363.4	365	1122.7	7.7	2.16	0.81	0.83	2.45

Table 5. Calculated statistical parameters of measured variables in high height.

Variable	Total skidding time (second)	Net skidding time (second)	Skidding distance (m)	Winching distance (m)	Winching slope (%)	Number of logs	Load volume (m^3)	Skid way slope (%)
Average	1464	1345	387.5	18.6	4.76	1.6	12.47	3.57
Minimum	565	565	90	9	0	1	6	1.12
Maximum	3264	2024	750	31	10	4	26	5.93
St. Deviation	527.08	401	186.7	5.1	2.6	0.87	3.24	1.3

Table 6. Statistical parameters of hourly rate of production in three areas.

	Number of cycle	Average skidding distance	Average	Standard deviation	Minimum	Maximum
Low height	48	440	6.57	1.22	4.04	9.33
Middle height	40	562	8.42	1.12	5.62	10.23
High height	55	485	9.56	1.39	7.3	12.4

Table 7. ANOVA model.

Variation source	Sum of squares	df	Mean squares	F-value	P-value
Regression	230.712	2	115.356	72.178	0.00
Residual	223.751	140			
Total	454.463	142			

Table 8. Duncan test of hourly production rate in three areas (level=95%).

Area	**Number**	**1**	**2**	**3**
Low height	48	6.57		
Middle height	40		8.24	
High height	55			9.56
Sig		1.00	1.00	1.00

The relationship between skidding distance variable, as influencing variable in all three areas, and net skidding time, was examined using scatter plot points. This is shown in Fig. 1.

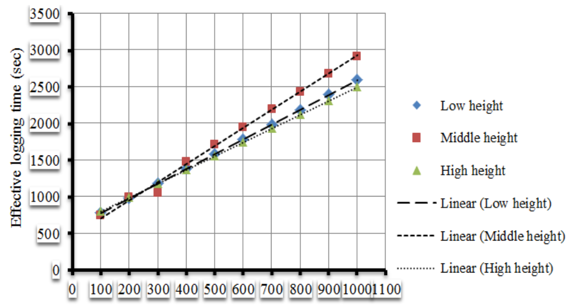

Fig. 1. Effect of skidding distance on logging time

Skidding distance has the main influence on skidding time (Lotfalian, 2011). In all three areas skidding time is a function of skidding distance, and fitted to an increasing linear curve. Load volume is another influencing factor in skidding time, that its diagram (Figure 2) is an increasing hyperbolic.

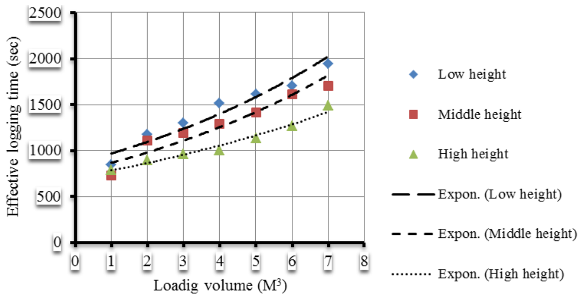

Fig. 2. Correlation of loading volume and logging time.

Habitat differences in altitude from sea level lead to differences in log characteristics and consequently quality as well as log volume. So the number and volume of logs in each cycle can have different effects on skidding time. In figures 3 and 4, the average volume and number of each cycle in three study areas have been studied.

From logs' genus perspective, based on the number of trees in low height, hornbeam with 45 percent is more than the others which is due to intense exploitation of the species of oak that has been done in the past years (Taheri & Pilehvar, 2008). 20% of trees are *Parrotica persica* species. In middle height, beech with 40 percent has the largest share, but still hornbeam and *Parrotica persica* with 44% has large share. 90% of the logs are made of beech but not hornbeam, oak and *Parrotcia persica*.

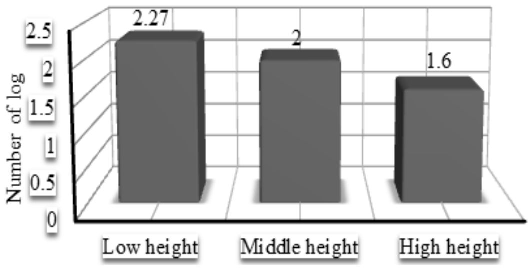

Fig. 3. Compare of average number of log per cycle.

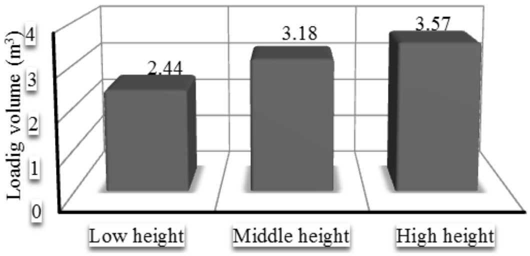

Fig. 4. Compare of average of logging volume per cycle.

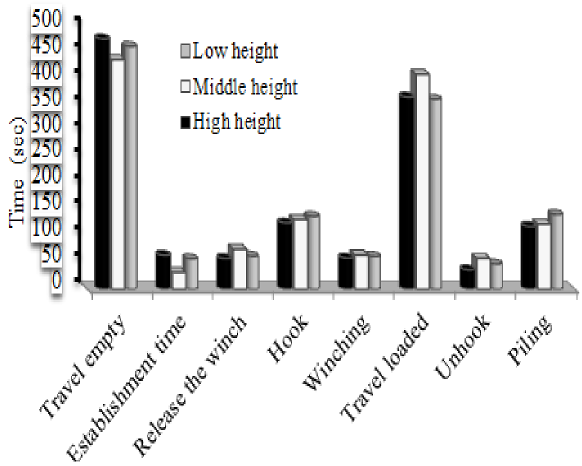

Fig. 5. Compare of average of elements time.

Elements of skidding cycle

Figure 5 shows a comparison of average time taken for each element of skidding cycle in three study area. As seen three elements of empty travelling, loaded travelling and piling logs in depot have the largest share in total skidding time.

Delays

Delays are generally divided into three categories: 1- Mechanical. 2- Personal. 3- Operational. Personal and Operational delays are preventable with proper planning, however, mechanical delays related to skidder such as: hoses rupture, puncture, skidder off, difficulty in opening the winch cable and the cable breaks, are unpredictable. Figure 6 represents each delay's share per three study areas. In each of the three areas personal delay had the largest share in total delays.

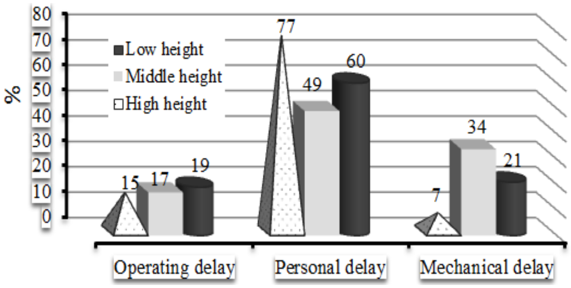

Fig. 6. Percentage of delays on total skidding time in areas.

Hourly rate of production

The hourly rate of production including net skidding time was equivalent to 6.57 m^3/h in low height, 8.24 m^3/h in middle height and 9.57 m^3/h in high height. As seen in Table 6 skidder performance is different in each of three areas. In order to compare the performance of skidder production in all three study areas, the hourly rate of production including net skidding time per cycle in each area was calculated and compared using the statistical comparison model. Regarding the test results in Table 7, sig amount 95% level is equal to 0.00, so there is a significant difference between the hourly production rates of skidder in three areas. To examine more closely the issue, a supplementary test was used to determine differences between areas. Duncan is one of the commonest tests for average comparison. According to the test results shown in Table 8, it is observed that there are significant differences between three study areas.

Discussion

The aim of this study is to compare the hourly production rate performance of skidder Timberjack 450C in three different habitats considering altitude from sea level, differences in factors affecting skidding, mathematical model predicting skidding time, and hourly production quality. As effective factors in the discussion, it is observed that skidding distance in each three area is involved in the model as an influencing principle; consequently skidding distance in every habitat is the most important reason. Volume variable and number of loads were entered to the model in low height. the number of loads due to low quality and low log diameter, caused by log genus that are generally hornbeam and *Parrotica persica* and increasing number of loads in each cycle, entered into the model in low height. With increasing the altitude of sea level, logs become mostly beech because of their thick and high quality stem; they are the most important industrial species of northern forest. (Saeed, 1995). The average number of logs in each skidding cycle in low height is 2.27 logs. In middle height and high height by increasing the quality of logs in each cycle there will be a decrease of 2 and 1.6 logs in each cycle, respectively.

Results showed that in all habitats, by increasing skidding distance and load volume, skidding time will increase. However, the effect of volume increase in each cycle intensifies but the effect of increase in distance is linear. Log quality differences due to differences in the type and forest species in different habitats, is a factor that affects the volume and number of loads as well as skidding elements like hooking cable time and piling logs in depot.

Average load volume due to increase in the number of beech log from high height to low height is respectively 2.44, 3.18 and 3.57 m^3 in each cycle. Accordingly, skidding elements that are associated with the number and volume of logs, show significant changes by increasing altitude from sea level. Average hooking cable time from low height to high height is respectively 139, 133 and 126 seconds that we see 33 percent reduction of time in high height. In piling element spent time had a 16 percent reduction from low height to high height.

The greater the number of logs in each load, the role of choker man and skidder driver will be more important and more sensitive. It is suggested that in low height and forests with low log quality, a more skilled driver and choker man should be used. There were no differences in the delays of different habitats. Personal delay has the most shares in all three areas. The hourly production rate has an increasing procedure from low height to high height and the difference has a significant function. However, the difference in average skidding distance in all three areas is little. The reasons for reduction in hourly production rate are habitat's conditions and quality of logs.

The sensitive and unique situation of northern Iran forests demands technical planning as well as economical one, because the aim of planning and different researches are extracting timbers not only with low cost but also with considering environmental issues and minimum destruction. Designing skidding path with considering cost and timing is so influencing. These issues were observable in studied parcels, as twisting paths had increased transferring time.

The aim of the study is to enhance the needed information of machineries' performance for the executives in forestry planning. It is suggested by accurate analyzing of the commonest machine in forest utilization, that skidder's owners by knowledge of differences in skidder performance in different altitude conditions should have a plan in using machines and work force based on their abilities. Skidder performance is less significant in low height forest, but by using skilled work force and integrated planning we can minimize personal and mechanical delays as well as elements of skidding cycle time, with this strategy an increase in hourly production rate of skidder, one can decrease the costs and increase incomes.

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