International Journal of Natural and Engineering Sciences 2 (3): 99-103, 2008
ISSN: 1307-1149 www.nobel.gen.tr

Productivity and cost of wheeled skidder in Hyrcanian Forest

Meghdad Jour GHOLAMI* Baris MAJNOUNIAN
Department of forestry and forest economicsFaculty of Natural Resources University of Tehran, Iran

*Corresponding Author
E-mail: mjgholami@gmail.com

Received: May 14, 2008
Accepted: July 09, 2008

Abstract

Wood transportation from harvesting unit to the roadside landing devotes the most expensive pertaining to logging operations. Heavy machines in wood transportation are imported tools; however they have very high hourly costs per hour and depreciation rates which oblige us to find appropriate transportation methods (approaches) for reducing costs. This research aims at evaluation of the theory in which more production results in reduction in the cost. The research also attempts to offer an analysis of production and cost of a skidder (Timberjack 450C) thorough an application in Educational and Experimental Forests of Kheirood. In the application, the time elements and effective factors in turn time of skidding operation were investigated based on 44 turns. The results indicated that the total production with and without delays in skidding with Timberjack 450C skidder was 8.22 and 8.88 cubic meters per hour, respectively. The cost of skidding using with and without delays was $7.41 and $6.86 per cubic meter, respectively.

Key words: Wheeled skidder, Timberjack 450C, productivity, cost, time study.

INTRODUCTION

Ground-skidding system is the process of moving trees or logs from the cutting site to a landing or roadside where they will be processed into logs or consolidated into larger loads for transport to the processing facility or other final destination. In the Hyrcanian Forest located in north of Iran, extraction with ground-skidding equipment is the most common system and also the one that tends to cause the greatest environmental problems.

Iran is considered to be amongst the low forest cover countries (LFCC), with the forest cover of 7.4% of the country area. Hyrcanian Forest has a total area of 1.85 million hectares comprising 15% of the total Iranian forest and 1.1% of the country's area [1].

The combination of the timber type and topography limit harvesting mechanization to perform transport operations. Rubber-tired skidders are used on the more gentle slopes and on skid roads on steeper terrain. Crawler tractors are used on steeper topography to skid direct to the landing. In steep terrain that is not accessible by ground-based machines, Felled trees are processed by chain saw into logs and then hauled by mules [2]. Regardless of the type of skidding equipment used, machines with an appropriate size and power configuration for the operation should be selected. Many countries restrict ground skidding to slopes of less than 30 percent (17°) except for short distances [3]. In north of Iran, this limit is 25 percent [4].

Many studies were carried out on productivity and cost of harvesting and logging operation and factors affecting the machine performance [5, 6, 7, 8, 9, 10, 11, 12, 13]. Bjorheden and Thompson [14] mentioned that the knowledge gained in the study of forest work is used to improve operational efficiency through better planning and control of future work. The purpose of forest work study is to provide a method for developing the knowledge needed to make good decisions in this complex environment. Akay *et al.* [15] studied the productivity of mechanized harvesting machines such as: skidder, feller-buncher, harvester, loader and forwarder in Turkey. Abeli [16] analyzed and compared the production rates and costs of three forest road construction machines (Ford County 1164 tractor, D4D and D6D Caterpillar bulldozers). Result showed that differences in production rates were attributed mainly by the type and the size of the machine, driver's working experience and the nature of the terrain side slope. Productivity and cost of two skidders, Timberjack models 460 and 660, were evaluated while operating in a loblolly pine plantation performing a clearcut harvest in the Southeastern US. Productivity without delimbing was 46.7 tones per PMH for the model 460 and 51.7 tones per PMH for the model 660. Cost per tone was $1.70 for the model 460 and $1.90 for the model 660 [17].

In north of Iran, Sobhani and staurt [2] evaluated the harvesting system with using Clark 66BDS wheeled skidder in first time and until now a couple of studies on productivity and cost of skidding machines have been reported by several researchers. Feghhi [18] assessed two mechanized forest harvesting systems including Madil 046 in high lead system and combination of both Clark 66 BDS wheeled skidder and komatsu D65 crawler tractor in Shafaroud Forest. Naghdi [19] studied optimum road density in tree length and cut to length systems using Timberjack 450 C and mentioned that the productions of Timberjack with and without delay were 13.6 and 17.1 m^3/h, respectively.

Because of high investments in forest utilization, planning and management for work and machines are very important. Of very important issues in forest utilization are the finding of proper machines and combination of them based on time study and skidding models. Machines in wood transportation are imported and have high cost per hour and depreciation which obliges us to find methods (approaches) for reducing costs. These machines are usually designed to suit the working conditions of the producer's country.

This research aims at evaluation of a theory in which more production lowers the cost and attempt to offer an analysis of production and cost of skidding operation (Timberjack 450C) in Educational and Experimental Forests of Kheiroud. Also the purpose of this research is to give contribution to gaining knowledge of the productivity and cost of the specified machine in skidding logs.

MATERIALS & METHODS

Study area

The research was carried out in compartment No. 221 of Namkhaneh forest management unit, in Kheirood Educational and Research Forest Station, with the altitude ranging between 1050 and 1190 meters above the sea level and lies on an eastern aspect. Rainfall ranges from 1420 to 1530 mm/year, with the heaviest precipitation in the summer and fall. Temperatures are moderate, ranging from a few below 0^0 C in December, January, and February to +25 °C during the summer. The forest stand was uneven aged and its main type was fagetum with average growing stock of 356 m^3/ha and multistoried structure. Soils have developed from cretaceous rock and are deep heavy clays with weak drainage and high hydro morphology. Cutting regime and silvicultural method were selection system and cuts were done as group-selection and single-tree selection. Trees to be removed were felled, delimbed, topped, and bucked into logs motor-manually. The logs were skidded by wheeled cable skidder to the roadside landings.

Data collection

Field data were collected during June and July of 2004. The continuous time study method was used to determining the production of Timberjack 450C. Fig. 1 shows the ground-based skidding in Kheirood Forest. The time elements considered in the skidding work cycles include: travel empty, releasing the winch, choker setting, winching, travel loaded, unhooking and decking. During this time study technical, personal and operational delays were recorded. In addition to measuring skidder working cycle time with a deci-minute stop watch, independent variables expected to affect on skidder productivity were documented. Variables included skidding distances (meter), slope of trails (%), number of logs per turn, and of load volume. In order to determine the number of required sampling, first a pre inventory was done to specify the time variance of skidding cycle without delay time and then 25 working cycle were time studied for this machine. Finally, 44 work cycles were collected for Timberjack 450C.

RESULT and DISCUSSION

Model

The SPSS 11.0 statistical programme has been applied for developing regression equation of time consumption. Table 1 shows the Summary of time study variables for this skidder. Regression analysis with the stepwise method between independent variables was performed on time study data to develop an operational cycle time equation for this machine. The dependent variable is skidding time per cycle without delay (T).

Figure 1. Timberjack 450 C Wheeled cable skidders

Table 1. Summary of time study variables for Timberjack 450 c skidder

Factor	Mean	Standard dev.	Min	Max
Travel empty (min)	1.91	1.48	5.43	5.41
Releasing the winch (min)	1.79	1.27	0.32	5.66
Choker setting (min)	3.13	1.94	0.35	8.6
Winching (min)	3.96	2.24	0.33	9.82
Travel loaded (min)	2.18	1.24	0.73	5.58
Unhooking (min)	0.85	0.36	0.16	1.9
Decking (min)	1.36	0.67	0.11	3.31
Total delay time (min)	0.04	0.18	0	0.91
Operational delay (min)	0.86	2.05	0	10.25
Technical delay (min)	0.31	0.89	0	4.41
Personal delay (min)	1.21	2.12	0	10.25
Delay free time (min)	16.41	6.95	4.08	23.59
Total time (min)	15.19	5.96	4.08	27.48
Skidding distance (meter)	184.6	121.8	18	458
Slope of trail (%)	2.25	1.32	5	27
Turn volume (m^3)	2.68	1.32	0.26	6.17
Number of log	0.54	21.46	1	6

Equation 1 shows the regression equation of time consumption using Timberjack 450 C skidder.

$$T = 4.142 + 1.988 \times N + 0.01769 \times D + 1.093 \times V \quad (1)$$

Where:

T = skidding time without delays (min/cycle)

D = skidding distance (m)

N = number of logs per cycle

V = load volume per cycle (cubic meter)

However, in wood extracting with Timberjack 450 C; skidding distance, number of logs, and volume per cycle were entered in model at significant level $a = 0.05$. The multiple correlation coefficient (R^2) 0.786 are interpreted as 78.6% of total variability, which are explained by the regression equation with Timberjack 450C. The significant level of ANOVA shows that models are significant at $a = 0.05$ (Table 2).

Table 2. ANOVA table for regression equation in Timberjack skidder

Factor	SS	df	MS	f	Sig.
Regression	1203.86	4	401.28	49.1	0.000
Residual	326.82	40	8.17		
Total	1530.68	43			

Productivity

The production (m^3/hr) of skidding with this machine can be obtained by using the production and time data as follow:

Unit Production = TP / TT (2)

Where,

TP = total extracted volume (m^3)

TT = total skidding time (hr)

The hourly production (m^3/hr) with delay time, for Timberjack was 5.93 and 8.22 m^3/hr. The measured production for this machine without delay times was 8.88 m^3/hr. Hourly productions of skidding without delay times was more than production (m^3/hr) with delay times. However, the average empty and loaded travel speeds of Timberjack 450C skidder were 1.4 m/s and 1.6 m/s, respectively. Loaded travel was performed in a higher speed than travel empty in skidding because of downhill direction. Fig.2. shows that production of Timberjack which decreases sharply, as the distance increases.

Costs of skidding operation

In order to determine the skidding cost, we used proposed model by Forest and Range Organization. Machine costing in US$ based on 2004 prices for Timberjack 450C was used. A purchase price of $222,222 was used, with an interest rate of 19%, an insurance and tax rate of 5% of the purchase price, a machine life of 10 years, and a utilization rate of 62%.

Table 3 shows the summarized machine costing of this machine. Total cost of skidding per hour was $60.9. The unit cost per cubic meters was $7.41 for the with delay times while the unit cost without delay times was 6.86 US$ per cubic meter.

The effect of each variable factor on skidding time and cost was studied by changing one variable while holding the other variables constant at their mean value. Figures 3, 4 and 5 show the effect of skidding distance, load volume and annual usage on skidding cost respectively within the recorded range of variables. Result showed that increasing in each variable on this machine caused to linear increase in cost and only with increasing the annual utilization in skidder, skidding cost per cubic meters decreases with respect to power.

Table 3. Machine costing in US dollar ($) based on 2004 prices for Timberjack 450C

Cost parameter	Cost (US $)
Fixed costs	
Depreciation	20000
Interest	23800
Tax and Insurance	2580
Total F. C. per PMH	3.2
Operating costs	
Maintenance and Repair	20
Fuel and Lubricant	5.2
Tires	3.56
Cable	1.32
Total O. C. per PMH	2.65
Total Machine Rate	58.0
Labor cost	2.89
Total System Cost	60.9

Analysis of work element and delay times

Figure 6 shows the distribution of elemental times per skidding with Timberjack 450C. The most time is spent winching the logs in skidding with Timberjack (24% of total time). In addition 54% of skidding time was devoted to three working cycle as following: releasing the winch, choker setting and winching. The main reason for increasing of these cycles was referred to the cut-to-length system which using in this research. Felled tree are bucked motor-manually in logs with 6 meters maximum length, therefore for providing an enough loaded volume, from 1 to 6 logs were prepared for skidding in each cycle with both machines. Sorting these logs to a load for skidding with both machines was also a time consuming task. Approximately 93% of each skidding cycles was devoted to productive activities. The percentage of delay times, relative to total time of working for this machine is shown in figure 6.

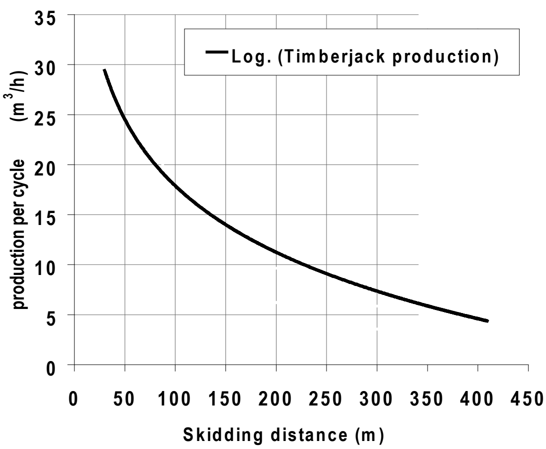

Figure 2. Hourly production (m^3/h) of Timberjack versus skidding distance

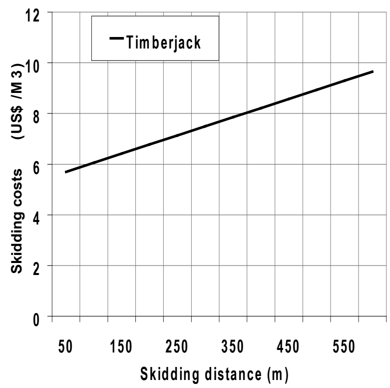

Figure 3. Skidding cost (US$/h) of Timberjack versus skidding distance

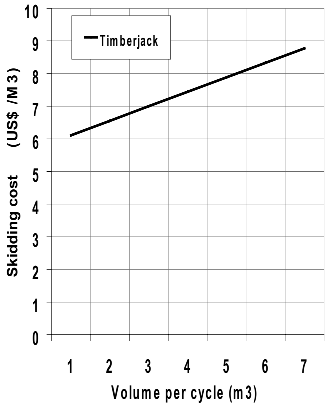

Figure 4. Skidding cost (US$/h) of Timberjack versus load volume

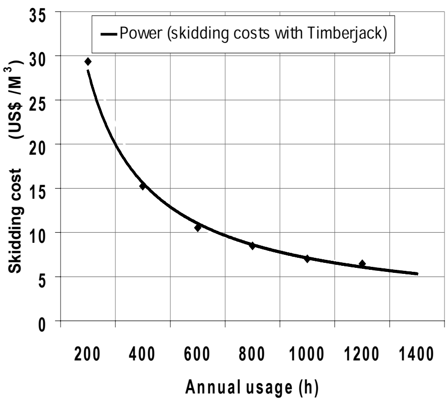

Figure 5. Skidding cost (US$/h) of Timberjack versus annual usage

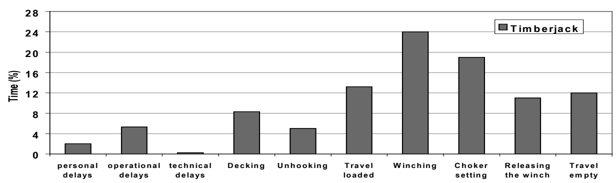

Figure 6. Percentage of work element in a cycle time

CONCLUSION

As comparing with other studies which carried out in Hyrcanian Forest about skidding machines productivity, the production of Timberjack 450C in this study was very low. The main reason for increasing of skidding time and decreasing the production of this skidder was referred to the cut-to-length system which using in this research. For example, Naghdi [19] mentioned that the productions of Timberjack with and without delay were 13.6 and 17.1 m^3/h, respectively because of using tree-length methods. Managing and control of delay time can be decreased the skidding cost in this machine.

However, in wood extracting with Timberjack 450 C; skidding distance, number of logs, and volume per cycle were entered in model at significant level $a = 0.05$. The multiple correlation coefficient (R^2) 0.786 are interpreted as 78.6% of total variability, which are explained by the regression equation with Timberjack 450C. An hourly production of skidding without delay times was more than production (m^3/hr) with delay times. The most time is spent winching the logs in skidding with Timberjack (24% of total time). In addition 54% of skidding time was devoted to three working cycle as following: releasing the winch, choker setting and winching. The main reason for increasing of these cycles was referred to the cut-to-length system which using in this research.

Although skidding distance was generally the most important variable since it effects cycle time more than other variables, in this study, the number of logs per turn by using cut to length system was most important variable in Timberjack 450C and the most of the time spent in providing a sufficient volume in each cycle. Result of this research can be also useful for in forest road network and logging planning.

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