Time study and skidding capacity of the wheeled skidder Timberjack 450C in Caspian forests

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ABSTRACT: This study was carried out in a steep and difficult terrain. Trees were logged downhill to the landing by a wheeled skidder Timberjack 450C. Selection cutting was performed on a 66-hectare tract with an average slope of 30%. The elemental time study method was applied to develop the skidding time predicting model. In this study 43 working cycles were included. The skidding cycle time was mainly affected by skidding distance, winching distance and interaction between skidding distance and slope. The gross and net production rate was 20.51 and 22.93 m^3/h, respectively. The unit cost considering the gross and net production rate was 6.31 and 6.22 USD/m^3, respectively.

Keywords: wheeled skidder Timberjack 450C; working efficiency; init cost; skidding

Due to the higher initial cost of harvesting machines, larger diameters and crowns of hardwoods and the relatively steep terrain in Caspian forests motomanual harvesting and a wheeled skidder are still the most commonly used system in this region. Primary wood transportation is one of the most sensitive and the most expensive operations and a hard level of forest utilization (Dvořák 2005). Nowadays, with the expansion of mechanization, it is necessary to determine machine efficiency in skidding operations. Information on the productivity, costs and applications of the logging system is the key component in the evaluation of management plans for the rehabilitation and utilization of Caspian forests. With the disappearance of traditional harvesting and the need for suitable forest mechanization systems, it is essential to transform the forest harvesting sector (Heinimann 1999). One of these transformations is the use of suitable machinery with high efficiency. The Timberjack 450C skidder, which has been imported from Canada, is one of the machines that are used for a ground-based skidding system in order to extract logs from the stump area to a roadside landing. Previous studies addressed the production and costs of harvesting stands under different machine and harvest prescriptions.

Jones (1983) conducted a time study on a 60-acre tract with three thinning treatments in the north of West Virginia. Time studies showed that the hourly felling production increased while the skidding productivity decreased from the treatments 45% to 60% and to 75% of the residual stocking. Regression equations were later developed based on the above time-study data, which can be used for estimating production rates and costs for similar thinning operations.

Howard (1987) took a different approach to estimating timber harvesting production and costs with skidders by collecting shift-level data on fuel consumption, repairs, maintenance and other operating costs. Productivities of grapple skidders were investigated in extracting full southern pine trees. They reported that the principal variables affecting the skidding cycle time were a skidding distance, machine flywheel horsepower, number of bunches grappled and number of trees per turn.

Huyler and Ledoux (1991) conducted the production analysis of the thinning of hardwood using small tractors instead of larger ground-based skidders. The productivity and costs of five small tractors were identified and compared using a computer program. The study reported that small-scale logging machines are feasible but the type of machine, careful site selection and layout are critical to ensure a profitable operation. Compared to the larger equipment these small tractors were more suitable and economic in the thinning of small stands with less soil compaction and less residual stand damage.

Landford and Stokes (1996) compared two logging systems including a feller-buncher/grapple skidder system and a harvester/forwarder system in the thinning of an 18-years-old loblolly pine plantation. The cost per cord was about 0.14 USD higher for the skidder system than for the forwarding system using cut-to-length wood and about 3.77 USD lower than for the forwarding system using 7.5-foot wood. Kluender et al. (1997) studied the productivities of rubber-tyred cable and grapple skidders in southern pine stands and found that grapple skidders were considerably faster and more productive than cable skidders. They also indicated that the productivity of this grapple skidding was sensitive to a skidding distance, stem size, number of stems in a load and harvest intensity. Lortz et al. (1997) conducted further analysis of the southern pine felling with chainsaws and produced several equations for estimating the felling times and productivity. Holmes et al. (2002) studied the productivity of a rubber-tyred skidder in conventional logging. They indicated that the productivity of the skidder was 22.39 m^3/h and the unit cost was 1.99 USD/m^3. Minette et al. (2004) stated that the operation cost of the forwarder was 60.70 USD/ha and the unit cost was 1.74 USD/m^3 and the energy consumption rates were 2.76 g/kWm^3. Werner (2004) stated that the productivity of the wheeled skidder per skidding cycle was 4.49 m^3 in block 1 and 4.41 m^3 in block 3 in Bolivian tropical forests. Naghdi et al. (2005) stated that the unit cost of the skidder Timberjack 450C was 1.53 USD and the variables including skidding distance, volume per turn, winching distance were significantly entered to the model. Sabo and Porsinsky (2005) stated that with skidding distance of 250 m (the average for the researched area), the possible productivity of Timberjack 240C under described work conditions is 12 m^3/PMH and the skidding costs of 2.2 €/m^3.

The aims of this study were:

1. The analysis of a continuous time study of skidding with a wheeled skidder Timberjack 450C in Caspian forests.
2. The estimate of production rates and unit costs of the skidder Timberjack 450C.

MATERIALS AND METHODS

This study was carried out in compartment 231 in Chafroud forests in the Guilan province in the north of Iran from July 15th to August 10th, 2007. The altitude ranged from 1,350 to 1,550 m above sea level and the average annual precipitation was 1,100 mm. The forest was uneven-aged *Fagetum* (*Fagus orientalis* Lipsky) with the average growing stock 320 m^3/ha. The slope of the compartment was 20 to 60% and the aspect of the slopes was northern. The total volume of production was 1,900 m^3 and the skidding of logs was done from the stump area to roadside landing by a ground-based skidding system. The skidder type used in this study was wheeled skidder Timberjack 450C, with the power of 177 HP and the weight was 10,257 kg. Table 1 shows the characteristics of the study area.

Times and operational variables were measured using a stopwatch and recorded on paper (Cubbage, Gorse 1984; Ledoux, Huyler 1997; Egan 2003). The work cycle for each operation consisted of certain elemental functions and factors (Ozturk 2005). The times for each function and the value of each factor were recorded in the field. The functions of the wheeled skidder were travel empty, establishment time, release and pulling, hook, winching, travel loaded, unhook, piling.

The variables recorded for the wheeled skidder were skidding distance from landing to stump, number of logs per turn, tree species, mid diameter, ground slope and winching distance.

43 cycles of the wheeled skidding were observed in the field. The number of observations varied depend-

Table 1. Characteristics of the study area

Characteristics	Study aspect	Characteristics	Study aspect
Forest district	Chafroud	Skidding way	downhill
Compartment number	231	Average field slope (%)	30
Altitude (m a.s.l.)	1,412	Silvicultural system	selection cutting
Aspect	Northern	Species	beech, alder
Number of workers	5	Maximum skidding distance (m)	679

Table 2. The statistics of operational variables of cable skidding in the study area

Variable	mean	Standard deviation	minimum	maximum
Number of logs per turn	1.53	0.59	1.00	3.00
Skidding distance (m)	288.90	149.40	84.00	679.00
Volume per turn (m^3)	2.71	1.16	1.00	5.91
Winching distance (m)	9.73	6.35	2.50	28.00
Ground slope (%)	–18.95	–9.03	–28.00	–5.00
Skidding cycle time and elemental times (min)				
Travel empty	3.74	1.98	0.9	9.65
Establishment time	0.22	0.17	0.00	0.83
Release and pulling	0.22	0.19	0.02	1.05
Hook	0.29	0.32	0.05	1.8
Winching	0.48	1.07	0.02	6.52
Travel loaded	3.35	1.65	0.82	9.01
Unhook	0.22	0.26	0.04	1.53
Piling	0.85	0.57	0.08	3.39
Skidding cycle time*	9.37	3.90	4.5	19.88
Delay	0.99	1.07	0.00	5.14

*skidding cycle time per tree does not include delays

ing on the amount of time required for collecting time study data. Each log was measured for dbh/mid diameter to the nearest centimeter. The Minitab 13.1 statistical program was used to analyze the data.

In addition to the total skidding cycle time we must considered delay time. The delay times and the reasons for the delays were also recorded. Three categories of delays were used in the delay analysis as personal delays, mechanical delays and operational delays, which represent delays associated with the principal operating functions of the system.

It was assumed that the skidding time per cycle is a function of the above-mentioned variables. The stepwise regression model was applied to the develop a model. In this method, if any variable has a significant effect on the RMS (Residual Mean Squares) of the model, it would be used in the model.

RESULTS AND DISCUSSION

Table 2 presents the statistics of operational variables of wheeled skidding in the study area. Table 3

Table 3. Average time and share of time segments

Elemental times of working cycle		Time (min)	Time (%)
Travel empty		3.74	41
Establishment time		0.22	12
Opening the winching cable		0.22	2
Closing the winching cable		0.29	3
Winching		0.48	5
Travel with load		3.35	35
Unhook		0.22	3
Setting and removing the logs		0.85	9
Delays	operation	0.52	–
	mechanical	0.28	–
	personal	0.19	–

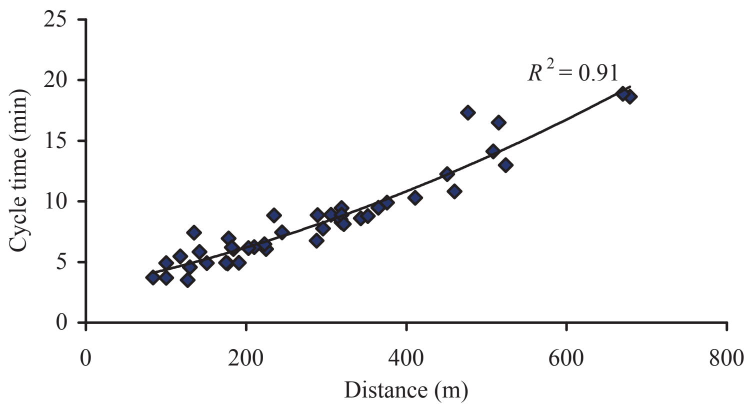

Fig. 1. Effect of skidding distance on skidding time per cycle

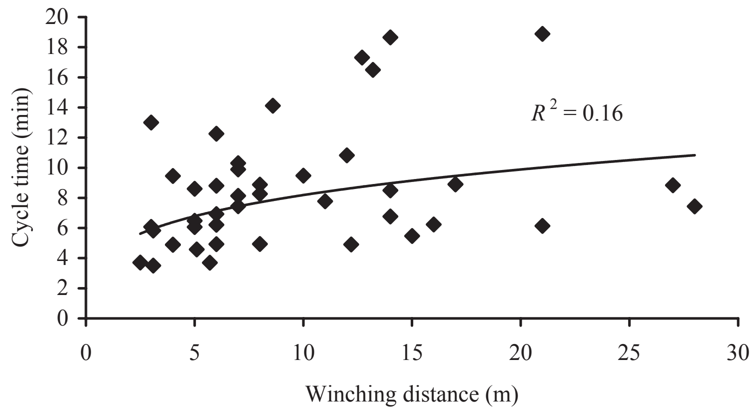

Fig. 2. Effect of winching distance on skidding time per cycle

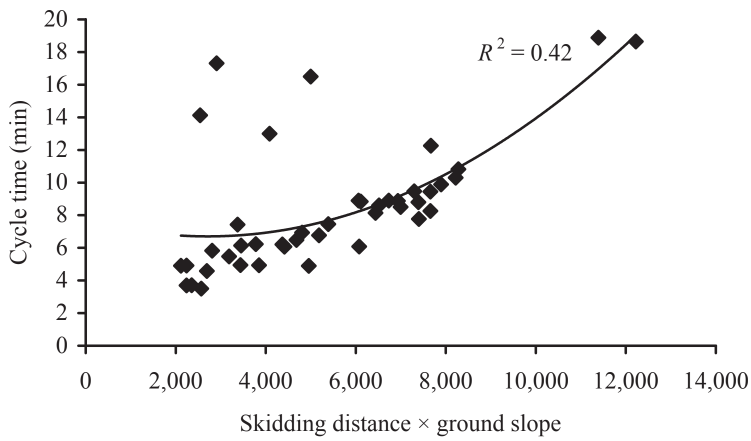

Fig. 3. Effect of interaction between skiding distances and ground slope on skidding time per cycle

shows the average working time and the share of elemental times of working cycle obtained in the Chafroud logging area with the skidder Timberjack 450C.

The gross and net productivities of Timberjack 450C for different distances were 20.51 and 22.93 m^3/h, respectively. Estimates of hourly costs of the cable skidding were computed using the machine rate method (Miyata 1980). The unit costs with and without delay times were 6.31 USD/m^3 and 6.22 USD/m^3, respectively. These costs are dependent on the average skidding distance (∅ 290 m).

The average lost time is 0.99 min per working cycle. Lost times (delays) were taken from different places in the working area. These places were loading area, unloading area and skid trails. A total of five workers were operating in the skidding system.

The stepwise regression analysis was applied to the time study data base to develop a delay-free cycle time equation. The significant variables included skidding distance in meters (Fig. 1), winching distance in meters (Fig. 2) and interaction between skidding distance and slope (Fig. 3).

The cycle time equations calculated for the Timberjack 450C took the following form:

$$Cycletime = 2.19 + 0.0272D + 0.0899L - 0.000274DS \quad \text{(min)}$$

$R^2 = 0.93$

Table 4. ANOVA model

	Sum of squares	df	Mean square	*F*-value	*P*-value
Regression	596.82	3	198.94	186.06	0.000
Residual	41.70	39	1.07		
Total	638.52	42			

where:
D – skidding distance (m),
L – winching distance (m),
DS – interaction between skidding distance and slope.

This multiple correlation coefficient of 0.96 is interpreted as the 93% of total variability, which is explained by the regression equation. The significance level of the ANOVA table (Table 4) shows that the model is significant at $\alpha = 0.01$.

The Minitab 13.1 statistical program was applied according to its series of phases in Table 2.

These series are independent variables. The dependent variable is total time (I). The stepwise regression analysis was applied. The most effective variables with 99% confidence intervals are:

$$I = 0.279 + 0.712A + 1.20B + 5.78C + 4.21D - 1.20E + 1.08F + 0.63G + 1.85H$$

where:
A – travel empty,
B – establishment time,
C – opening the winching cable,
D – closing the winching cable,
E – winching,
F – travel with load,
G – unhook,
H – setting and removing the logs (min).

$R^2 = 0.90$, $F = 45.53$, Durbin-Watson = 3.08

The Durbin-Watson coefficient value was found as 3.08. If this coefficient is near 2 or above, this means that autocorrelation between residues is negative.

CONCLUSION

The skidding cycle time and the travel loaded time as well as cable skidding productivity were primarily affected by skidding distances but winching distances and interaction between skidding distances and the ground slope were other major factors that also influenced elemental times and productivity. The travel empty was solely affected by skidding distance. The gross and net production rate was 20.51 and 22.93 m^3/h, respectively. The average production cost considering the gross and net production rate was 6.31 USD and 6.22 USD/m^3, respectively. The production equation is a useful tool for helping logging planners. The results of this study indicate that the skidding distance and the winching distance have the highest influence on skidding time. As we showed in Table 3, personal delays are the most important among three kinds of delays. These kinds of delays show incorrect management in skidding operations in the study area. Without any delays, we will have 0.09 USD profit per m^3.

The felling sequence should be chosen with consideration for efficiency and chokers should be used. Further yearly working times of the machine should be increased.

Directional felling can be useful to diminish the skidding cost. For the more efficient operation of the wheeled skidder Timberjack 450C, a minimum of two workers should be employed. In this study three landings were used. The mean of delay times was 0.99 min per turn, which was 0.52, 0.28, and 0.19 min per turn for operational delays, mechanical delays and personal delays, respectively. Obviously, operational delays are the most frequent, based on this that products are not properly ready for the skidding from the forest. After the operational delays, mechanical delays were the most frequent. In order to prevent a decrease in their efficiency and to reduce delay times and fuel consumption, the maintenance of machinery must be performed according to the technical specification and in a timely manner. An adequate manner of spare parts should be maintained in order to prevent any loss of time in the case of urgent maintenance-repair works. Because of steep slopes, high elevations and sensitive sites, harvesting and extraction operations in the Caspian forests of Iran need to be carefully planned and executed. This study is conducted to establish a quantitative base for harvesting management and planning in Iran. Information on the productivity, costs and application of harvesting equipment and system is a key component in the evaluation of management plans for the rehabilitation and utilization of the Caspian forests.

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Časová studie a pracovní výkonnost kolového traktoru Timberjack 450C v kaspických lesích

ABSTRAKT: Studie byla provedena ve sklonitých a náročných terénech. Stromy byly soustřeďovány na odvozní místo kolovým traktorem Timberjack 450C. Výběrová seč byla prováděna na ploše 66 ha o průměrné sklonitosti 30 %. Časová studie byla aplikována na vyvíjený model pro predikci času na soustřeďování dříví. V časové studii bylo zahrnuto 43 pracovních cyklů. Pracovní čas na soustřeďování dříví byl ovlivněn především vyklizovací a přibližovací vzdáleností a interakcí mezi přibližovací vzdáleností a sklonitostí terénu. Průměrná výkonnost práce byla se zohledněním časových ztrát během směny 20,51 m^3/h a 22,93 m^3/h v operativním čase. Průměrné výrobní náklady činí 6,31 USD/m^3, v případě nezapočtení ztrátových časů se náklady snižují na 6,22 USD/m^3.

Klíčová slova: kolový traktor Timberjack 450C; výkonnost práce; provozní náklady; soustřeďování dříví

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