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Original Article

Productivity of Hauling by Tajfun MOZ 500 GR Cable Yarder in Turkey

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ABSTRACT

The extraction of timber is very important despite the process is difficult, expensive, time consuming, and has concerns with work safety. The extraction operations are used human, animal, and machine power. The purpose of this study is to investigate the productivity of the Tajfun MOZ 500 GR cable yarder during the extraction of timber from spruce stands in northeast Turkey. The research results imply that some working characteristics of the MOZ 500 GR cable yarder such as load volume, yarding distance, speed of the carriage, and time consumption per phase have an important impact on the productivity of the cable yarder. The results indicated that the productivity of MOZ 500 GR cable yarder was 8.39 m^3/h for an average yarding distance of 90 m. Besides, the daily productivity of cable yarders was found at 67.12 m^3. The cable yarders seem ideal for use in the steep terrain. The use of cable yarders in wood production works is more ideal than other production techniques (human, animal, and tractor) in terms of productivity, speed, and work safety.

Keywords: Logging, time study, volume, yarding distance

Introduction

Wood harvesting is carried out in two stages. The first stage is to take the cut wood raw material to the nearest forest road edge. This phase's name is haulage or primary transportation. Another phase is transportation of wood raw material from the forest depot to the nearest forest road edge. The haulage operation is the stage where environmental impact is also greatest in wood production (Aykut, 1984; Öztürk, 2004a).

Extraction operations in forestry are shaped according to the nature of the forest, the technical equipment used, the intensity of production work's intensity, and various other factors (Akay et al., 2004). Manpower, animal power, and machine power are used in these mentioned operations. The haulage operations with human and animal power are not fast and economical. Besides, damages and economic losses occur in the transported product when hauling was done by human power (Gürtan, 1975; Ünver & Acar, 2005). In our country, modified tractors, skidders, and cable yarders are used as machine power in the hauling operations. The tractors and skidders are very fast and economical. But, these machines cause environmental damage such as soil compaction, bark injuries, and so on. Soil degradation and soil compaction are the result of heavy machinery use during hauling operations (Cambi et al., 2015).

The use of cable yarder is more effective in wood production and affects large areas (Spinelli et al., 2010). When the slope exceeds 40%, the use of cable yarder is the best solution (Spinelli et al., 2015). Cable yarders are especially widely used in the northeast of Turkey. But, tractors are used all over the country in haulage operations (Öztürk, 2004b; Öztürk & Şentürk, 2010). Cable yarders have some advantages in extraction of wood. They can be used in both uphill and downhill transport (Erber et al., 2017).

Due to the topographic structure of the Artvin region, forest areas are located on mountainous and steep slopes. The fact that the forest terrain is highly sloping and hilly makes it mandatory to use cable yarders and tractors for hauling. Various harvesting systems have been developed to achieve economic and environmental sustainability under variable conditions, such as terrain conditions and labor power (Abbas et al., 2018; She et al., 2018). Tractors and skidders are used for short distances and slopes of up to 40%. In addition, as the slope of the slope increases, the use of cable yarders becomes mandatory. The hauling operations done by cable yarders

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are more sensitive to the environment (Çağlar & Acar, 2005; Öztürk & Şentürk, 2006). Cable yarding is the most common steep slope harvesting technique worldwide (Spinelli et al., 2015). The use of tower yarders, even if potentially more productive, environmental friendly, and faster to mount and dismantle, is still limited by the absence of forest roads on slopes (Munteanu et al., 2019).

Koller K300, Urus MIII, and Gantner cable cranes have been used in our country for many years. In addition, MOZ 500 GR cable yarders were purchased in 2019 and started to be used in wood harvesting operations. Approximately, Koller K300, Urus MIII, and Gantner cable cranes have been used in Turkish forestry for about 35 years. Although these machines are old, they are still used in mountainous areas. MOZ 500 GR cable yarders have given great strength to wood harvesting operations.

This study examined the productivity of Tajfun MOZ 500 GR cable yarder used for the first time in Turkey. At the same time, the working principles and techniques of cable yarders were closely studied and the use of these cable yarders in mountainous areas such as the Artvin region was investigated.

Methods

Study Area

The field where the research was carried out was Ortaköy Forest Enterprise within the Artvin Forest Management Directorate. The total area of Ortaköy Forest Enterprise is 23 685.50 ha. Although there are 7776.90 ha of deforested areas in the region, there are 6747.00 ha of normal forest, 9211.60 ha of degraded forest, and a total of 15 968.60 ha of forest area. Ortaköy Forest Enterprise is located between 41° 54′ 33″ and 42° 06′ 42″ east dectitudes and 41° 12′ 04″ and 41° 22′ 41″ north latitudes in geographical terms. This region has generally high altitude, steep, and has a very inclined structure (Figure 1).

The main tree species in the region are *Abies nordmanniana*, *Picea orientalis* (L.) *Linked*, *Fagus orientalis*, and *Quercus* sp. It consists of stands made of pure and mixed stands with each other. The area where the plan unit is located is in the black sea climate zone. The domestic climate type of this region is rainy in all seasons and has the character of a marine climate in terms of temperature. The highest place in the region is the Karchal Mountains with 3415 m, and the lowest place is located at the intersection of the Turbid stream and the Çoruh River with 240 m. The total length of the road in the region is 243,6 km, and the road density is 15.30 m/ha (GDF, 2021).

Data Collection

The study was conducted in the Pırnallı village affiliated with the Ortaköy Forest Enterprise, within study site compartment no 231 in August 2019. The study was conducted in *P. orientalis* L. forests in the Artvin region, Turkey. At the harvesting area, trees were felled, delimbed, and cross-cut into final assortments before yarding, using a chainsaw. The team consisted of five workers, of which one acted as cable yarder operator, three workers as choker setters at the loading site, and one worker at the edge of the forest road. The operator had at least 10 years of experience with cable yarders.

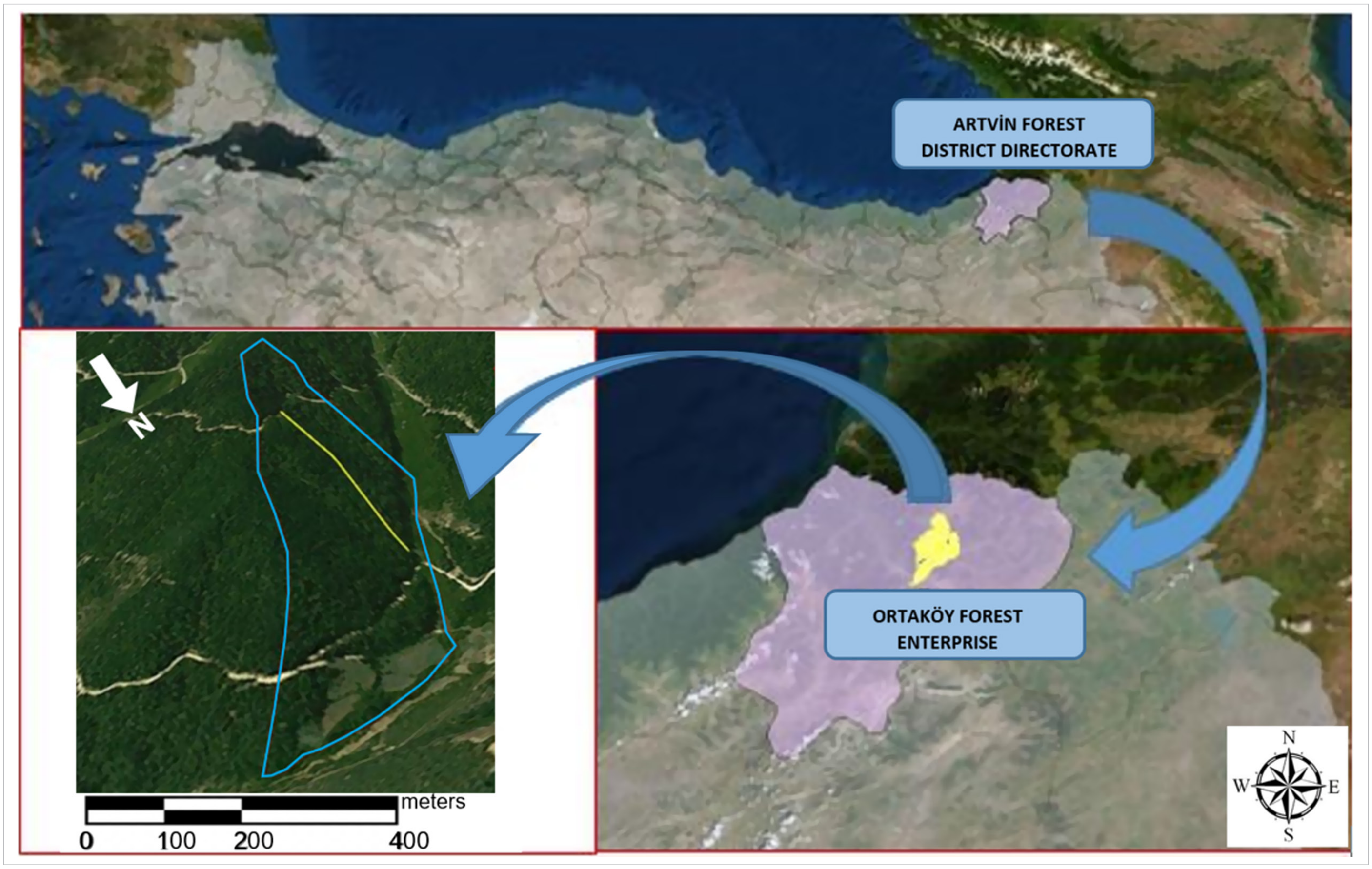

Figure 1.
Artvin Forest District Directorate Ortaköy Forest Enterprise and Study Area.

The cable yarder was installed on the forest road. Tajfun MOZ 500 GR cable yarder was installed at an average length of 300 m. The slope of the production area is between 70% and 80%. The altitude of the production area is 1665 m on the road mountain station side and 1597 m on the valley station side. Logs were yarded uphill. Logs are located decently within the production area at distances of 50–150 m. The mounting time of the cable yarder took 1 h, and the dismantling time took 30 min. Yarding distance was determined with a steel tape measure. Load size was determined by measuring the length at the diameter at mid-length of all logs in each load.

In forestry operations and harvesting operations, the productivity of machines is found with time measurements. Time study is an important research tool used in comparing productivity at forest harvesting systems across varying conditions (McDonald & Fulton, 2005). Time study is a set of procedures for determining the amount of time required, under certain standard conditions of measurement, for tasks involving some human, machine, or combined activity (Wang et al., 2003). Time measurement studies were conducted in several different studies for forest machines (Aykut, 1984; Cağlar, 2002). In addition, for productivity of using forest machines are used different time measurement techniques. It was checked according to the purpose of the study and the expression was found sufficient. As a result of time studies, one-time, hourly, and daily yields of the cable yarder were calculated.

In the harvesting area, in the study conducted with Tajfun MOZ 500 GR cable yarder, working conditions were examined in the production fields, and work times, tt, and time losses appropriate to the workflow were detected by digital chronometer by using a continuous time measurement to determine the working efficiency. The data obtained from the study areas were evaluated from a statistical point of view, and the effects of the active factors on the effective working time were tried to be revealed. Data from individual cycle observations were analyzed with the regression technique in order to calculate meaningful relationships between productive time consumption and work conditions, such as yarding distance and load size. A total of 40 cycles were made during the time measurements.

In order to conduct time studies, the work segments of the cable yarder at a time were determined as follows:

1. Travel of unloaded carriage (a)
2. Lowering time of the load hook (b)
3. Hooking of load (c)
4. Retracting time of the load hook to the carriage (d)
5. Travel of loaded carriage (e)
6. Lowering time of the load hook in unloading area (f)
7. Unhooking of load (g)
8. Retracting time of the load hook to the carriage (j)
9. Delay time (k)
10. Total time (tt)

Technical Characteristics of Tajfun MOZ 500 GR Mobile Cable Yarder

Tajfun MOZ 500 GR cable yarder is a Slovenian product, the line is used by mounting on a tractor and it receives its power from the tractor to which it is connected. When necessary, the cable yarder is remotely controlled, hauling is done by a tower and carriage (Figure 2).

Figure 2.
(A and B) Tajfun MOZ 500 GR Cable Yarder; (C) outer Panel; (D) Control Panel.

Table 1.
Tajfun MOZ 500 GR Cable Yarder and Tümosan 8105 Tractor Technical Properties

MOZ 500 GR Cable Yarder	Technical Specifications	Tümosan 8105 Tractor	Technical Specifications
Weight	3800 kg	Engine power	105 HP
Required tractor power	105 HP	Number of cylinders	4/Turbo Intercooler
Skyline length	500 m	Cylinder volume	4.1 L
Skyline	500 m/18 mm (diameter)	Max. torque	400 Nm
Mainline	500 m/9 mm (diameter)	Tank	115 L
Fixing cable	45 m/16 mm (diameter)	Gear	16 forward/16 back
Tensile strength	60 kN (kilonewton)	PTO type	Independent
Max. working height	8 m	PTO speed	540–540E cycle/min
Max. carrying height/capacity	2.8 m /1900 kg	Lifting capacity	4000 kg
Swing angle	180°	Air conditioning	Existing
Tire sizes	400/60R15.5	Radio/MP3 player	Existing
Oil tank capacity	120 L	Weight	3500 kg
Control system	Remote control	Tire dimensions	
Fuel consumption	3 L/h	Front	340/85R24
Productivity	50–70 m^3	Back	280/70R24
Carriage weight	240 kg	Maximum torque speed	1500 cycle/min

Source: Anonymous (2019).

The technical specifications of the Tajfun MOZ 500 GR cable yarder and the Tumosan 8105 tractor to which it is mounted are given in Table 1.

Results

As a result of time studies conducted on this cable yarder, it was determined that 27 293 m^3 of logs were extracted in a total of 3 h and 20 min of the cable yarder (Figure 3). The logs located under the skyline of the cable yarder and within a side towing distance were transported by the carriage. Logs that were far away in the cable yarder corridor were driven to the bottom of the cable yarder by manpower and transported from there by connecting to the loading hook of the cable yarder.

Within the scope of the study, Tajfun MOZ 500 GR cable yarder shows the results of haulage operations conducted by the cable yarder. The cable yarder was established at a length of about 300 m, and the average transport distance was also determined as 90 m in this study. The following graphs show the relationship between the transport distance and the tt and productivity (Figure 4).

As seen in Figure 4, tt increases as the transportation distance increases, on the other hand, the productivity of the cable yarder decreases depending on the distance as the transportation distance increases.

Working time values related to extraction by Tajfun MOZ 500 GR cable yarder were measured. The average time of these work periods was determined and the proportional distribution of the tt is given in Figure 5.

The average load volume within the scope of the study was calculated as 0.63 m^3/cycle. On average, the volume of a log transported was 0.69 m^3 and it was determined that it has a length of 4 m. The average productivity at the work site was 8.39 m^3/h. The daily productivity of the cable yarder was found to be (8 h) 67.14 m^3. Daily fuel consumption was measured by the volume method. The average fuel consumption per working hour was 6 L/h (Table 2). This result was higher than the fuel information (3 L/h) indicated in the fuel catalog related to the cable yarder (URL-1, 2021). The fact that the fuel was high was believed to be due to the fact that the cable yarder was new, the process of

Figure 3.
Images from the Workspace.

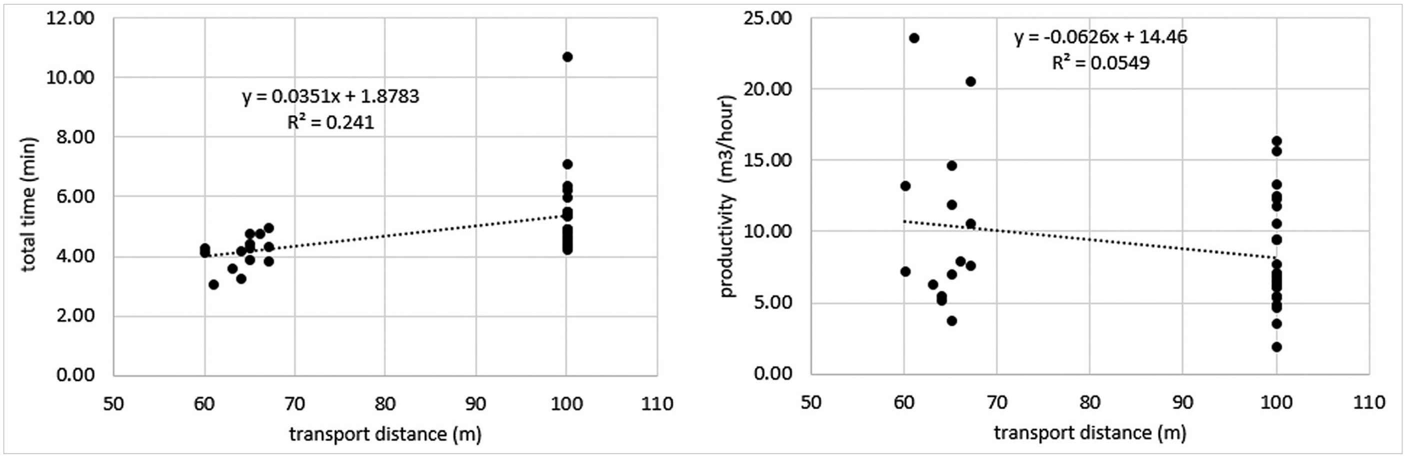

Figure 4.
The Relationship between Transportation Distance and Total Time (tt) and Productivity.

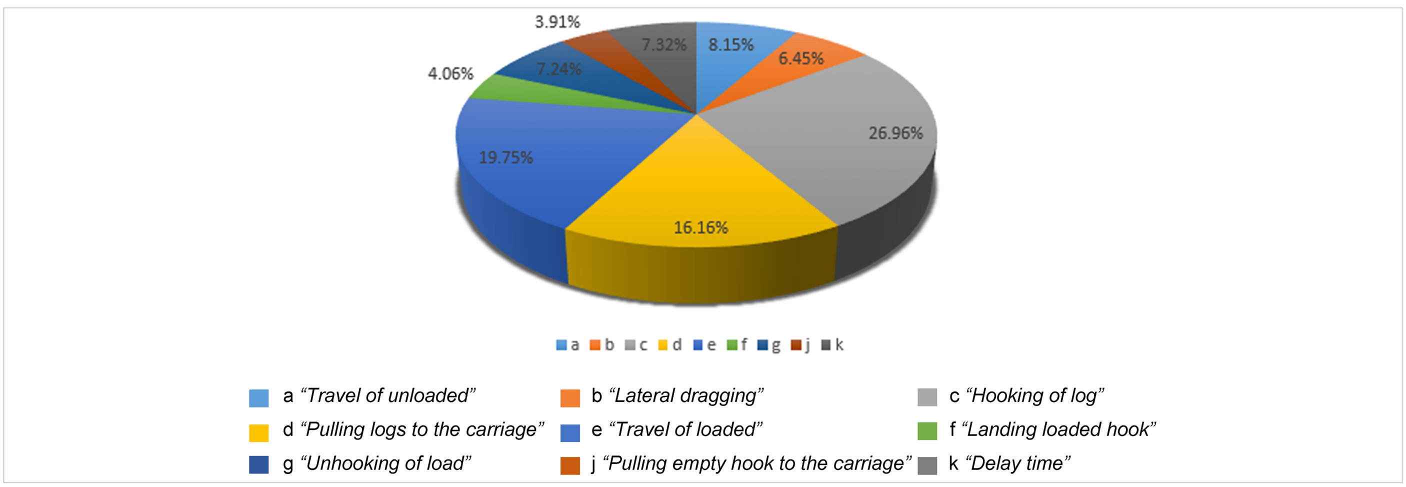

Figure 5.
Proportional Distribution of Work Segments and Total Time of a Cycle.

the operators getting used to the machine, and the working area was difficult.

When Table 2 is examined, it is seen that the time of connecting the hooking of load took the longest time by 80.3 (27%) in the time measurement study of the cable yarder, while the time of taking the retracting time of the load hook to the carriage took the shortest time by 11.6 s (4%). The average value of delay times in tt was found to be 21.8 s.

The working period of the cable yarder, which has the largest share in the average time of one trip, is the time of "hooking of load" with 26.96%.

As a result of the correlation analysis conducted between the factors affecting the working time of the cable yarder and the work periods: "the highest positive correlation ($r = .778$) was found at the level of 99% significance between delay time and total time." Then, the time periods of "retracting time of the load hook to the carriage" and "travel of loaded carriage," respectively, were the ones that affected the tt the most ($r = .478$ and $r = .446$, respectively). These values were followed by "hooking of load" and "travel of unloaded carriage" at the level of 95% significance (Table 3).

Variance analysis was used to test whether the data confirmed the statistical model. Statistically, the significance level of 95% was taken as the

Table 2.
Average Values Obtained from the Collected Data

Transport Distance	a	b	c	d	e	f	g	j	k	tt	Log Length	Log Diameter	Log Volume	Productivity	Fuel Consumption
(m)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(m)	(cm)	(m³)	(m³/h)	L/s
90	24.3	19.2	80.3	48.1	58.8	12.1	21.5	11.6	21.8	296	4	45.3	0.69	8.39	6

Independent variables: a, b, c, d, e, f, g, j, k; dependent variable: tt.

Table 3.
Correlation Analysis Results

		a	b	c	d	e	f	g	j	k
Total Time	**Pearson Correlation**	−.022	.212	.405*	.478**	.446**	−.039	−.212	.371*	.778**
	Sig. (2-tailed)	.892	.195	.010	.002	.004	.814	.194	.020	.000

* The mean difference is significant at the 0.05 level; ** Correlation is significant at the 0.01 level (2-tailed).

basis. As a result of the analysis, it was found that the model as a whole is significant and this relationship is linear (sig. = 000).

For the 95% confidence level between the tt and independent variables during the extraction with Tajfun MOZ 500 GR cable yarder;

$$tt = 14852 + 1738a + 1184c + 0790d + 1211e + 1122f + 0955k$$

a regression model was created. In the regression analysis, the step-wise model method was chosen, from the selected models, the sixth model was selected. The reason for this is that the value of model R^2 is high compared to other models. The relationship between the independent variables specified in the regression model and the dependent variable, "total time (dec)," is strong and was ($R^2 = .962$). Additionally, the Durbin–Watson (DW) coefficient was found to be 2.147 in the model (Table 4). It shows that there is no autocorrelation in the performed model on which a DW test value was conducted. In this context, it can be said that there is no autocorrelation in the model obtained.

In the scope of this research, a linear and positive correlation was found between the dependent variables [travel of unloaded carriage (a), lowering time of the load hook (b), hooking of load (c), retracting time of the load hook to the carriage (d), travel of loaded carriage (e), lowering time of the load hook in unloading area (f), Unhooking of load (g), retracting time of the load hook to the carriage (j), and delay time (k)] and the dependent variable (tt). This indicates that when an independent variable increases, the tt also increases.

Discussion

In this study, the productivity of MOZ 500 GR cable yarder under the conditions of our country has been examined for the first time. This article shows the results of research of yarding timber by the MOZ 500 GR cable yarder. The average load volume was 0.690 m^3/cycle and it consisted of two pieces. In this study, the productivity of cable yarder was 8.39 m^3/h and the daily productivity (8 h) of cable yarder was 67.12 m^3. In the Artvin region, hauling operations made by short-distance cable yarder were studied over the years. In a study conducted by Öztürk in 2004, the hourly efficiency of the Koller K300 cable yarder at a transport distance of 250 m was found to be 5.90 m^3/h (Öztürk, 2004). According to Aykut et al. (1997), the efficiency of transportation at 160 m from the Koller K300 cable yarder was 12.20 m^3/h. Another study conducted by Eroğlu and Erdaş (1999) found the efficiency of Koller K300 cable yarder at 190 m to be 4.85 m^3/h. A study by Acar and Gümüş (2000) conducted in the same region determined the efficiency at a 200 m of transportation distance in the Koller K300 cable yarder to be 7.86 m^3/h. Çağlar (2002) found the efficiency of Koller K300 cable yarder at 280 m distance to be 4.50 m^3/h. The efficiency value of the MOZ 500 GR cable yarder used in this study at a transport distance of 90 m was 8.39 m^3/h, which is higher than the cable yarders used in other studies. The fact that this cable yarder is new has caused its efficiency to be higher than other Koller K300 cable yarders. A feature of the cable yarder is that the skyline speed is set to two gears. In other words, the carriage can be started faster or slower by being empty or full.

Within the scope of this information provided, in this study, it was determined that the independent variables affecting the tt were "lowering time of the load hook," "travel of unloaded carriage," and "travel of loaded carriage," respectively. In order to reduce the impact amounts of these determined independent variables, that is, to indirectly reduce the tt, it is necessary to increase the speed of the cable yarder. However, it should be that the speed increase of the cable yarder can result in a number of disadvantages such as the fact that does not control the carriage, occupational safety, and so on. Another factor affecting the productivity of the cable yarder is "hooking of load." In order to fix this situation, depending on the terrain structure, the installation of the cable yarder should be done in such a way that it passes right through the middle of the working area where the logs to be transported are distributed, or the products should be brought near the corridor of the cable yarder establishment by pre-skidding.

Conclusion and Recommendations

In this study, the mounting time of the cable yarder was 1 h, while the dismantling time was 30 min. The mounting operations are the actual experience of the operator and workers, terrain slope, situation of weather, roughness, and vegetation covers. Stampfer et al. (2006) reported that while an uphill short corridor (150 m) can be installed on average in 6 h; a 500 m downhill corridor with single support would require 23 h. In this study, the mounting time has taken less time for 300 m installation distance. Mounting and dismantling times affect the work productivity for cable systems (Zimbalatti & Proto, 2009).

Table 4.
Model Summary

					Change Statistics					
Model	R	R²	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.981	.962	.955	15.81523	.006	5090	1	32	.031	2.147

Independent variables: a,b,c,d,e,f,g,j,k; Dependent variable: tt.

The advantages of cable yarders used in wood production works are very high. Especially in countries with forests in mountainous areas, cable yarders should definitely be preferred. The mini-yarders seem to offer a good solution to wood extraction on steep terrain, competitive with animal and winch logging in terms of productivity, cost, and operator comfort (Spinelli et al., 2010). Cable yarders used in combination with forest roads have high efficiency in wood raw material production. Therefore, we must also renew and develop forest road networks.

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