Evaluating Productivity and Cycle Time of Skidding Method with Farm Tractors in Bigadic Forest Enterprise Directorate in Turkey

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Abstract

In Turkey, mechanized harvesting methods have started to be used depending on the recent developments in forest industry, but advanced harvesting machines could not be used in national wide due to high operating cost and terrain conditions. The most common harvesting method is skidding with farm tractors since they are easily accessible and cost efficient. In this study, skidding method by a farm tractor in Bigadic Forest Enterprise Directorate was examined in terms of productivity and cycle time. The factors that affect the machine performance were also evaluated. It was found that the average time measurement of a cycle was 30.75 minute and the average productivity of tractor was found to be 4.75 m³/hour. The average volume and amount of skidded timber per cycle was about 1.80 m³ and 2 pieces, respectively. Among the factors evaluated in the study area, it was found that skidding distance had a maximum effect on the total cycle time and productivity. Unlike previous time studies, it was found that volume was relatively less effective on the total cycle time. This study revealed that the examination of the total time and productivity in terms of selecting and utilizing the appropriate harvesting technique can yield the best performance of the method.

Keywords: Skidding operation, Farm tractor, Time study, Productivity

1. Introduction

In timber extraction activities, transportation of forest products from stump to landing is a rather difficult, expensive and time-consuming activity (Eroglu and Acar, 2000). Many countries in the world, farm tractors have been used in forest operations when the terrain conditions and the size of the wood production are not limiting (Akay, 2005). Farm tractors equipped with appropriate forestry attachments are often used for timber extraction because they are versatile and cost effective (Spinelli and Baldini, 1992). Harvest systems consisting of farm tractors are the most popular systems for timber harvesting in Turkish forestry (Öztürk, 2014). Topographical structures restrict ground skidding to slopes of less than 30% except for short distance (Dykstra and Heinrich, 1996). Farm tractors are used for various forest harvesting tasks including felling, processing, extraction and hauling (Spinelli and Magagnotti, 2012). The high capacity farm tractors offer several potential benefits for forest operations. The high-power tractors can operate on difficult terrain and skid large amount of timber which may increase the productivity of tractors during skidding operations (Kluender et al., 1997). Modified farm tractors play an important role in skidding operation, even after the development of specialized forest articulated tractors (Zecic et al., 2006).

Forest harvesting requires extensive planning, including assessments with multiple criteria analysis (Eker et al, 2006). The most important criteria for suitable planning are productivity and cycle time. Many studies have been done in order to evaluate these criteria in the skidding operation. These studies have revealed that skidding cycle time is affected mainly by skidding distance, terrain conditions, ground slope, and log size (Najafi et al., 2007; Behjou et al., 2008; Gilanipoor et al., 2012; Ghaffariyan et al., 2013; Melemez et al., 2014). In this study, tractor skidding operation was examined to assess the efficiency of the tractor in the areas of Beydağ Forest Enterprise Chief (FEC). The objectives were to determine time consumption and productivity (m³/h) of tractor skidding while investigating the factors that affect the tractor performance.

2. Material and Methods
2.1. Study Site and Data

Study area is in Beydağ FEC within the border of Bigadiç Forest Enterprise, located in northwest Turkey (Figure 1). The total area of Beydağ FEC is 17195 ha. The commercial trees in the FEC are *Pinus brutia, Pinus nigra, Juniperus excelsa*, *Juniperus oxycedrus*, *Juniperus communis,* and *Fagus orientalis.* This study was applied at compartments of 135 and 136 in Beydağ FEC and skidding operations were executed on either skid road or skid trails. All skidding directions were loaded uphill and unloaded downhill. The terrain of the study area generally had a rough structure. In terms of soil structure, soils in the study area are classified as brown and lime-free forest soils within the humid forest soil belt except some areas in the southeast part of the study area. The study was conducted in *Pinus nigra* stand. There were two workers and one of them was tractor operator while the other one was carrying out the hooking and unhooking jobs. The work was carried out in May when the soil was in dry condition.
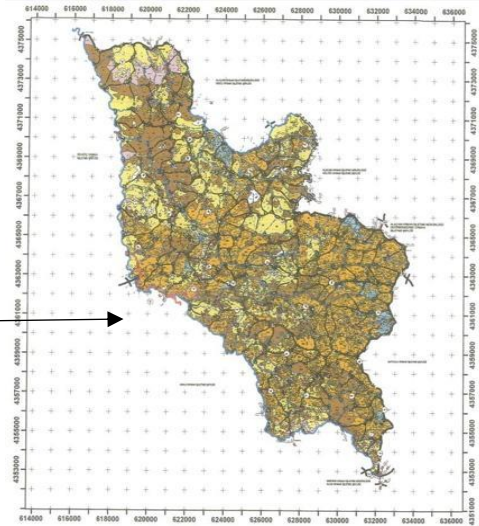

Figure 1. The study area

In this study, skidding was performed with a Fiat 54-C tractor which is modified for skidding logs on both skid roads and skid trails. During skidding operation, one end of the dragged timber is in touch with the ground (Figure 2). The technical features of the Fiat 54-C tractor are shown in Table 1.

Figure 2. Skidding with Tractor Fiat 54C

Table 1. Fiat 54C Technical Features

Features	Fiat 54C
Engine	Fiat 8035.06
Weight	2180 kg
Maximum engine power	55 HP
Cylinder/volume	3/2710 cm
Engine cycle	2500 d/d
Engine type	4 stroke injection diesel
Gas tank	54 lt
Tire size	Front:6.00-16 Rear:13.6/12.28 (54C- 12) Front: 6.5-16 Rear:14.9/13-28 (54C-13)

2.2. Measurements and Calculations

The productivity of the farm tractor was evaluated using time study method. Time consumptions of working stages during skidding were measured by repetitive time study method and time data were taken throughout the whole working day. The skidding distance was determined by using a measuring tape and the slope gradient of strip roads was measured by clinometer. The load volume were determined by measuring the diameter and length of each piece of timber under bark by using caliper.

The time study is an effective research tool used to compare the productivity of harvesting systems considering different factors (McDonald and Fulton, 2005). In this study, the effects of several independent variables including "Skidding distance", "Number of load" and "Load Volume" on the "total cycle time" as a dependent variable were measured. Total of 40 skidding cycles were recorded during farm tractor skidding to evaluate equipment productivity, and identify those variables that are most likely to affect it. All the statistical analyses were performed using the SPSS 21 software.
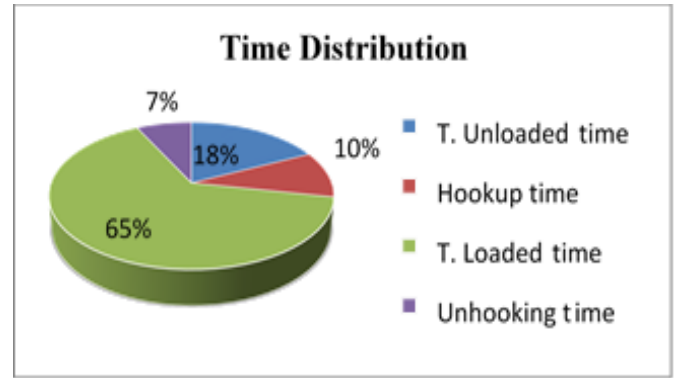

Figure 3. Time distribution in skidding with farm tractor

3. Results and Discussion

In this study, timber extraction was conducted with skidding distances varied from 100 m to 1000 m. The average skidding distance was found to be 385 meters. The skid road width was 2.5 m and the average slope of skid road was 4%. The most time consuming components of the total skidding time was travel loaded time, followed by travel unloaded time (Figure 3 and Table 2). Rest time, repair time or maintenance time of machine couldn't be included in work cycle, because they were not statistically significant in this study.

The average time measurement of a cycle was 30.75 minute and the average productivity of tractor was found to be 4.75 m³/hour. The average load volume and number of skidded timber was 1.799 m³ and 2, respectively. Factors affecting productivity and total cycle time were investigated using statistical analysis. Firstly, correlation analysis was performed to evaluate the relationship between productivity and two factors including volume value and total time (Table 3 and Table 4).

Table 2. Descriptive statistics of the mean value and standard deviation

	Min	Max	Mean	Std. Deviation
Skidding distance(m)	100	1000	384.75	285.120
Volume (m³)	0.173	3.848	1.799	0.899
Number of load	1.00	3.00	2.55	0.714
T. Unloaded time (min)	1.30	12.10	5.405	3.155
Hookup time (min)	1.00	6.20	3.087	1.728
T. Loaded time(min)	3.45	55	19.509	14.699
Unhooking time (min)	0.40	4.40	2.235	1.554
Time (min)	9.50	77.40	30.755	20.466
Productivity (m³/h)	0.578	12.686	4.749	3.344

Table 3. Correlation analysis between total time and volume

		Volume	Total Time
Volume	Pearson Correlation	1	0.145
	Sig. (2-tailed)		0.373
	N	40	40
Total Time	Pearson Correlation	0.145	1
	Sig. (2-tailed)	0.373	
	N	40	40

Table 4. Correlation analysis between productivity and volume

		Volume	Productivity
Volume	Pearson Correlation	1	0.625
	Sig. (2-tailed)		0.000
	N	40	40
Productivity	Pearson Correlation	0.625	1
	Sig. (2-tailed)	0.000	
	N	40	40

As a result of the analysis, it was found that the volume had a low correlation with total cycle time (0.145), while had a moderate correlation with productivity (0.625). The correlation analysis conducted to evaluate the relationship between the number of load and total cycle time indicated a low correlation with a value of 0.306 (Table 5). The relationship between the number of load and productivity was found to be very low with a value of 0.236 (Table 6).

The ANOVA analysis was conducted to investigate the effect of the number of load on productivity and total cycle time. The number of loads varied between 1 and 3 during the skidding operation. The effect of the number

of load for three groups (1, 2, and 3) was examined in terms of productivity. It was found that there was no statistically significant difference between the three classes since the (p) value being greater than 0.05 (0.228). The number of load and total cycle time of the skidding was found to be unrelated with the values of 0.139 (Table 7 and 8).

Correlation analysis indicated that total time was significantly associated with skidding distance with a value of 0.928. As the results of second analysis, there was an important inverse relationship between productivity and skidding distance (Table 9 and 10).

Table 5. Correlation analysis between total cycle time and number of load

		Number of load	Total time
Number of load	Pearson Correlation	1	0.306
	Sig. (2-tailed)		0.055
	N	40	40
Total time	Pearson Correlation	0.306	1
	Sig. (2-tailed)	0.055	
	N	40	40

Table 6. Correlation analysis between productivity and number of load

		Number of load	Productivity
Number of load	Pearson Correlation	1	0.236
	Sig. (2-tailed)		0.143
	N	40	40
Productivity	Pearson Correlation	0.236	1
	Sig. (2-tailed)	0.143	
	N	40	40

Table 7. ANOVA analysis for productivity and number of load

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	33.527	2	16.763	1.541	0.228
Within Groups	402.533	37	10.879		
Total	436.060	39			

Table 8. ANOVA analysis for total time and number of load

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1651.484	2	825.742	2.081	0.139
Within Groups	14683.338	37	396.847		
Total	16334.822	39			

Table 9. Correlation analysis between total time and skidding distance

		Skidding Distance	Total time
Skidding distance	Pearson Correlation	1	0.928(**)
	Sig. (2-tailed)		0.000
	N	40	40
Total Time	Pearson Correlation	0.928(**)	1
	Sig. (2-tailed)	0.000	
	N	40	40

Table 10. Correlation analysis between productivity and skidding distance

		Skidding Distance	Productivity
Skidding distance	Pearson Correlation	1	-0.571(**)
	Sig. (2-tailed)		0.000
	N	40	40
Productivity	Pearson Correlation	-0.571(**)	1
	Sig. (2-tailed)	0.000	
	N	40	40

The study showed that skidding distance was the highly correlated factor affecting total time and productivity. In order to investigate the effects of various skidding distances, it was grouped into three classes including 0-250 m (1), 251-500 m (2) and more than 500 m (3). The ANOVA test was performed to determine if there were any significant differences between the groups (Table 11). It was found that there was a statistically significant difference between the three groups since due to the (p) value (0.000) being less than 0.05. According to the Post-doc analysis results, there was a significant difference between groups 1 and 2 and between 1 and 3.

Table 11. ANOVA analysis for skidding distance groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	169.357	2	84.679	11.748	0.0000
Within Groups	266.703	37	7.208		
Total	436.060	39			

In a similar study conducted by Naghdi (2004) mentioned that the productivity of skidder was 17.1 m³/hour. Huyler and LeDoux (1989) determined that the total time per cycle was 34.14 min for 270 m skidding distance by Massey Ferguson tractor. In another study conducted in the mountainous area in Black Sea region in Turkey (Öztürk, 2010), it was found that hourly productivity was 11.35 m³ for 140 m and 7.7 m³ for skidding distance of 320 m. Gülci et al. (2018) conducted the efficiency analysis of a tractor which indicated that the average production rate of the tractor skidding was 5.72 m³/hr and 4.30 m³/hr for the worksites with 20% slope and 30% slope, respectively.

Abeli (1992) indicated that skidding productivity is affected by the number of logs per cycle. However, in this study it was revealed that the system productivity was not strongly influenced by the number of logs per turn. On the other hand, some of studies were indicated that there was a doubt that skidding distance significantly affected skidding cycle time and production rate (Liu, 1993). In a similar study, Gilanipoor et al. (2012) reported that effective independent variables of skidding time were skidding distance and slope of skid trail. The result of this study also showed that the farm tractor productivity was affected by skidding distance.

4. Conclusions

In the study, three factors (skidding distance, load volume, number of load) affecting productivity and total time were examined. It was determined that the work stage with maximum amount of time was travel loaded time of the farm tractor. Proportion of travel unloaded time and hookup times were found to be much less. When the effects of the factors were examined, it was found that skidding distance had an important effect on total time and productivity. On the other hand, the volume had the least effect on the total time. However, there was a moderate significant correlation between productivity and volume. The number of load was also found to have a low-grade relationship with productivity and total time. Increasing the average skidding distance during the wood production decreases the efficiency of harvesting equipment. Besides, the cost of skidding increases as the skidding distance increases in harvesting unit. Thus, the forest engineers should plan for shorter skidding distances in order to increase productivity while reducing the cost in timber extraction activities. On the other hand, the skid roads and trails should be located in the form of a network in harvesting unit.

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