Productivity and Cost of Rubber – Wheel-Tyred Tractor in a Northern Pine Plantation Forest of Turkey

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Abstract

This paper presents research results of the performance of "Massey Ferguson" farm tractor using whole stem harvesting method in pine plantations in northern Turkey. The elements of the skidding work phase were identified, 30 cycles were recorded for this study and productivity of tractor is done by time measurements. Skidding time per cycle was directly related to tractor type, skidding distance and number of whole stems hauled, and inversely related to harvest intensity. Skidding productivity was sensitive to skidding distance, number of whole stems in a load and stem size. In this study, skidding distance is average 295 m. Hourly productivity are 9,910 m³/hour for skidding distance of 295 m. The total cost of "Massey Ferguson" tractor is calculated as 22.98 USD/m³. The average fuel consumption is 3.5 l/hour.

Key words: ''Massey Ferguson" tractor, skidding, productivity, cost, time study

Introduction

In many regions of the world, farm tractors have been used in forestry, where the terrain conditions and the size of the forest operation are not limiting (Akay 2005). Harvest systems consisting of farm tractors and skidders are the most popular systems for timber harvesting in Turkish forestry. Especially, the modified farm tractors are used in many regions in Turkey. Farm tractors are often used in forest operations, particularly in small scale forestry. Some possible advantages, when compared to specialized forest machines, include:

- increased flexibility;
- lower capital investment (Johansson 1997).

On the other hand, farm tractors have very low initial costs and relatively low operating cost comparing with harvesting machine (Turk and Gumus 2010). 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 skid roads on steeper terrain (Gholami and Majnounian 2008). The mountainous areas and steep terrains are not accessible for skidders and farm tractors. Many countries of the world restrict ground skidding to slopes of less than 30 percent (17) except for short distance (Dykstra and Heinrich 1996).

Larger capacity farm tractors offer several potential benefits for forest operations. Powerful tractors can skid to larger timber. Thus, productivity of tractors may increase during skidding operations. Efficiency of skidding operations is dependent on hauling a skilled operator, a mechanically sound piece of equipment, and a sufficient volume of logs to be skidded, which is influenced by the stand conditions and the harvest prescription (Kluender et al. 1997).

The aim of this study is to perform a time study to determine the productivity of "Massey Ferguson" farm tractor in skidding of logs from a pine plantation forest. The structure of total consumed time, time standards of work phases and daily output standards for skidding distances (average 295 m) were established.

Material and Methods

Study Area

This study was permormed in August 2013. Study area is managed by Sile Forest Administration and this area was located in the northern Turkey (Figure 1). The research was carried out in compartment No. 37 of Sahilkoy forest management with the altitude ranging between 250 and 300 meters, above the sea level and lies to the north. The rainfall of this region ranges from 33.1 to 137.4 mm/year. The study area covered 3,000 hectares of a 25 years old plantation of the maritime pine (*Pinus pinaster* A.). The plantation is harvested in rotation usually every 25-30 years for this pine. Soils of this region are clay, sand and clay loam.

Skidding of the timber was performed by modified farm tractor harvesting system. Skidding operations

Figure 1. Research area

were carried out on either skid road or skid trails. All skiding operations was favourable (loaded uphill and unloaded downhill) and slope of skid road was changed between 3 and 17 percent. All trees were felled and delimbed with a chainsaw. The whole stem were skidded by farm tractor to the roadside landings. Skidding logs are whole stem and length of skidding stem is changed between 12 and 18 meters.

Technical Features of Farm Tractor

For this study in the research area a "Massey Ferguson" 285 farm tractor was used (Figure 2). It was modified for skidding on skid road and skid trails, which implies that one end of the dragged timber is in touch with the ground. This tractor was used to slope untill average 30%. It was eguipped with lift system. The lift system was added to back of tractor. The an edge of skidding timber were located on lift system. Tractor has a cab and noise level was minimal. The main technical features of the tractor are shown in Table 1.

Figure 2. Skidding by 'Massey Ferguson' farm tractor

Table 1. Technical features of 'Massey Ferguson' 285 farm tractor

Technical features	"Massey Ferguson"285
Motor Power	82 HP
Motor Type	'Perkins'
Cylinder number	4
Cylinder Volume	4.06 litre
Max. Torque	1,400 revolution per min.
Max. Revolution (Unload)	2,160 revolution per min.
Weight	3,470 kg

Data Collection

For productivity of farm tractor was done time measurements. Detailed time studies were conducted to collect data on skidding cycles and delays. Time study is an important research tool used in comparing productivity at forest harvesting systems across varying conditions (McDonald and 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, and combined activities (Wang et al. 2003).

The repetition time study method was used to determine the production of 'Massey Ferguson' tractor. The time elements considered in the skidding work cycles include: travel unloaded, hookup of a load, travel loaded and unhook of the load. Recorded data included productivity cycle time elements and other independent variables associated with each activity. During this time measurements delays were recorded. These delays were of two different shapes. These were operational delay and technical delay. Data recorded for each log included the diameter of logs and its length.

Variables included skidding distance (m) and load volume (m^3) per turn. In this study, 30 work cycles were collected for the farm tractor.

Results

Statistical Model

In this study, SPSS 21.0 statistical programme for developing regression equation of time measurements has been applied (Anonymous 2012). Regression analysis has been realized together with the enter method. Summary for the total skidding cycles is shown in Table 2. Total 30 skidding cycles were studied to develop a linear regression. The result of independent variables is shown in Table 2. The dependent varible is skidding time per cycle without delay (Total time – T). A regression model developed from the detailed time study using 'Massey Ferguson' tractor was as follow:

$$T = -36.880 + 2.053 \times V + 0.162 \times SD$$

T = Skidding time without delays (min/cycle);
SD = Skidding distance (m);
V = Volume per cycle (m³).

Table 2. Summary of time variables for 'Massey Ferguson'

Factors	Mean	SD	Min	Max
Travel Unloaded	4.06	0.45	3.1	5.1
Hookup of load	3.53	2.09	0.5	8.3
Travel Loaded	5.02	0.88	3.25	6.4
Unhook of load	1.27	1.14	0.20	3.5
Delay time	4	2.48	1	9
Total time (without delay)	14.28	2.59	11.2	21
Total time (with delay)	18.28	3.93	11.2	26.3
Skidding distance	295	20.32	265	340
Load volume	2,390	0.61	1.32	3.58
Number of logs	2	1	2	3

In this analysis, skidding distance, number of timber and load volume per cycle were entered in the model at significant level 0.05. The multiple correlation coefficient (R) were interpreted as 72% of total variability. The value of VIF is 1,001 and it was very small, see Table 3). Therefore regression model was not multicollinear one. Autocorrelation was determined with the Durbin Watson test. The Durbin Watson statistic fall within the range of 0 to 1 in this study. The Durbin Watson statistic was 0.727 indicating a positive autocorrelation (Table 4). The time consumption models of skidding were also checked by graphical statistical measures and the models were proved to be statistically significant (Figure 5). The regression analysis demonstrated random distribution (Figure 6).

Productivity

In this study, the hourly production without delay time for 'Massey Ferguson' farm tractor was

Table 3. Statistical characteristics of models based on a regression analysis

Model	Unstandadized Coefficients		*t*	Sig.	Collinearity Statistics	
	B	*SE*			Tolerance	VIF
(Constant)	-36.880	6.389	-5.773	0.000		
Volume	2.053	0.705	2.911	0.007	0.999	1.001
Distance	0.162	0.021	7.698	0.000	0.999	1.001

a. Dependent Variable: Time

Table 4. Values of the models based on the regression analysis

Adjusted *R* Square	*SE* of the estimate	*F*	Durbin Watson
0.70	2.3	34.777^{xxx}	0.727

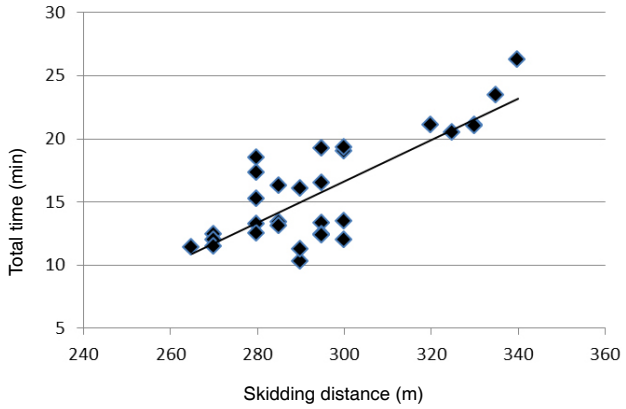

Figure 3. The percentage of work phases

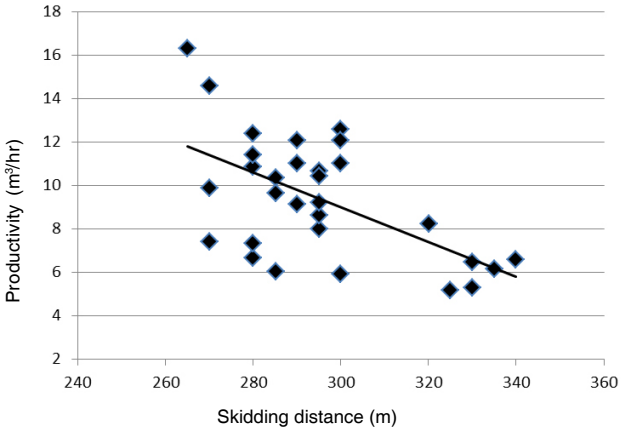

Figure 4. Relationship of skidding distance vs. total time

9.910 m³/hour for average 295 meters skidding distance. Therefore, production with delay time was 7.96 m³/hr. Hourly productions of skidding without delay times was more than production with delay times. The average total cycle time was 14.28 min for average 295 meters skidding distance. The two most time consuming components of the total skidding time were hookup of load and travel loaded time. For this study, average productivity rate of tractor was calculated as 9,910 m³/hr, approximately. Delays were 20.9% of the average skidding cycle time; delays ranged from 62.5% in personel delay to 37.5% technical delays.

Cost of Skidding Operation

The operation cost of the farm tractor was based on fixed cost and variable cost. Fixed cost included the cost of interest, depreciation, tax and insurance. The depreciation was calculated according to economic life of 10 years. The fuel consumption of tractor was 3.5 lt/hr. The lubricant costs were assumed to be 23% of the fuel cost. The total cost of 'Massey Ferguson' tractor is calculated as 22.98 USD/m³. Detailed costs of tractor shown Table 5.

Table 5. Detailed costs of farm tractor

Parameters	Cost (USD)
Fixed Costs	
Depreciation	2.00
Interest	2.20
Insurance and Taxes	0.72
Operating Costs	4.92
Repair and Maintenance	0.10
Fuel and Lubrication	8.61
Cable	0.04
Tires	2.10
Labour Costs	10.85
Labour	7.21
Total Cost	22.98

Analysis of Time Measurements

In this study, the most time is spent skidding of whole stem with farm tractor as 27.6% of total time. Total skidding time increased as the skid road slope and distance increased. The skidding distance affected skidding cost. A summary of skidding operations with farm tractor during the time study is shown in Table 6. The average delay-free time consumption of skidding was approximately 20% lower than the time consumption with delay. The average number of whole stem was 2, the average skidding distance 295 m, and the average volume for a cycle was 2.39 m³. Also, the average fuel consumption of farm tractor was 3.5 lt/hr. As shown in Figures 4 and 5 when the skidding distance increases, the productivity and total time of tractor is decreasing. An inverse relationship of productivity with skidding distance and a direct relation with volume skidded are shown (Figure 4). Therefore the highest productivity was found when the skidding distance was short and volume skidded was high.

Table 6. Total skidding cycle determined from the detail time study

Time	Travel Unloaded	Hookup load	Travel Loaded	Unhook load	Delay	Total time
Minute	4.06	3.53	5.02	1.27	4	18.28
Percent	22.20	21.03	27.26	7.85	21.66	100

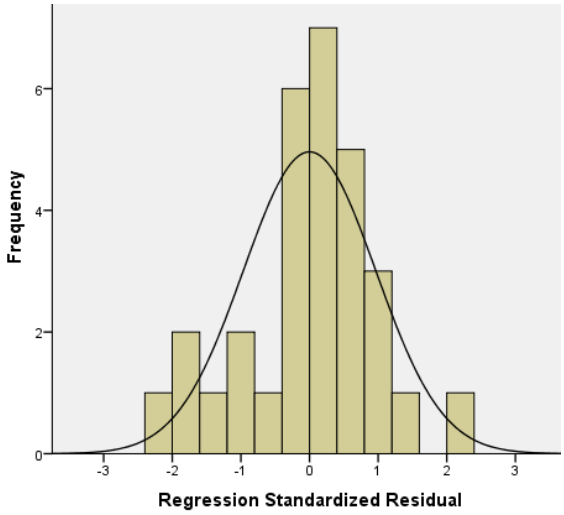

Figure 5. Relationship of skidding distance vs. productivity

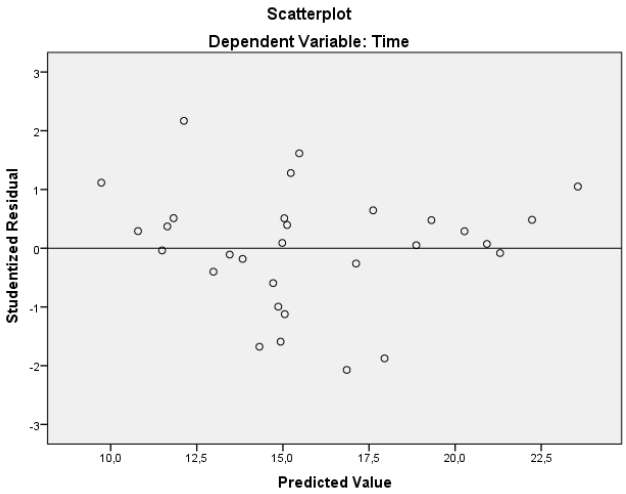

Figure 6. Random distribution of regression analysis

Conclusion and Discussion

This study presented a discussion on appliying timber skidding operations with farm tractor on skid road. The skidding operations by farm tractor can be limited by some factors such as skidding distance, tractor engine power, total volume per cycle, the number of log per cycle, skid road slope and experience of tractor operator. The farm tractor productivity was affected by skidding distance. Besides, during the farm tractor skidding operations, travel unloaded and loaded was affected by skid road slope. Travel unloaded and travel loaded collectively dominated the cycle time (Gilanipoor et al. 2012). In this study, the effect of distance on skidding was higher than that of skid road slope. The engine power of tractor is enough for skidding operations. But, the productivity of tractor is decreased than increased skidding distance. According to Mousavi (2012) et al., travel unloaded is the first element of skidding. The modelling of travel unloaded showed that it was highly dependent on the skidding distance. Travel loaded took the longest time share among different elements of skidding. Travel loaded is the most time consuming element of skidding.

In this study, the hourly production without delay time for 'Massey Ferguson' farm tractor was 9.910 m³/hour for average 295 meters skidding distance. The average total cycle time was 14.28 min for average 295 meters skidding distance. The total cost of 'Massey Ferguson' tractor is calculated as 22.98 USD/m³. Naghdi (2004) mentioned that the productivity of skidder

without and with delay were 17.1 and 13.6 m³/hour, respectively. Huyler and LeDoux (1989) found that the total time per cycle was 34.14 min for 270 m of skidding distance by 'Massey Ferguson' farm tractor. A similar study conducted in the mountainous area in the Black Sea region of Turkey (Ozturk 2010) reported that hourly productivity was 11.35 m³ for 140 m and 7.7 m³ for skidding distance of 320 m. In another study; operating cost for the skidder was calculated as 55.48 USD/SMH (Klepac and Rummer 2000).

Stem size was the most important factor in determining skidder productivity. Average skid distance and number of stems per load also determined skidding productivity. During the skidding operations, skidder engine power was a limiting factor (Kluender et al. 1997). Another a study, Turk and Gumus (2010) mentioned that average slopes of skid trails were between 13 and 31. The farm tractor have worked comfortable with these slopes during skidding operations. Previous research showed that the effect of slope on skidding time is higher that of distance. This could be explained by the fact that the machine is a speedy rubber tractor and low engine power (Gilanipoor et al. 2012).

The sum of the travel loaded, hookup of load, travel unloaded and unhook of load time constitute the production time for the tractor. Hook up, unhook and delay time are the fixed portion of the total time since the tractor is not moving during these periods. Trees were directionally felled, either away from or toward the assumed tractor position, so that the choker could be set at either the but top end of the stem.

Increasing the skidding distance and slope of skid road during the skidding operations decreases the efficiency of machines. At the same time, the cost of skidding increases in felling area. Therefore, in the felling areas forest engineers should use shorter skidding distances. Besides, the skid roads and skid trails should be arranged in the form of a network in production areas.

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