system for underequipped logging crews. However, size of the timber should be small enough to be handled by the workers while their dimension should be acceptable by the market.

To speed up the loading operation and increase productivity, development cooperatives have recently begun to turn to low-cost mechanized loading systems integrated with cable winch (Gülci, 2014). In this systems, forest products are pulled up to rear end of the truck platform by pulley mounted on rectangular frames. The pulling power of the winch is usually driven by gasoline engines or electric powered engines. Cable winch loading can be implemented at any location where a logging truck can travel along the roadside. Acar (2016) also introduced an alternative loading system where portable winch and polyethylene chutes were integrated for loading of timber products.

Timber loading operation plays important role in overall productivity and total cost of timber extraction activities. In this study, performances of two loading systems including traditional manual loading and electric powered winch systems were evaluated by using time and motion study based productivity analysis. The study was conducted during the extraction of Brutian pine timber in Mediterranean city of Osmaniye in Turkey.

2. Material and Methods

2.1. Study Area

The study was conducted in Brutian pine (*Pinus brutia* T.) stand of Bahçe Forest Enterprise Chief, Osmaniye Forest Enterprise Directorate located in the border of Adana Forestry Regional Directorate (Figure 1). In the study area is within the limits of 37° 11' 18" - 37° 10' 41" N and 36° 33' 44" - 36° 34' 46" East. The average ground slope and elevation are 32.73% and 683 m in the area.

2.2. Loading Operations

In the field, manual loading operation was carried out by party of five workers. During the operation, two workers pulled up the timber, which were previously bunched along the roadside, and transferred them to other two workers at the truck platform (Figure 2). The fifth worker helped them stacking the timber at the truck platform.

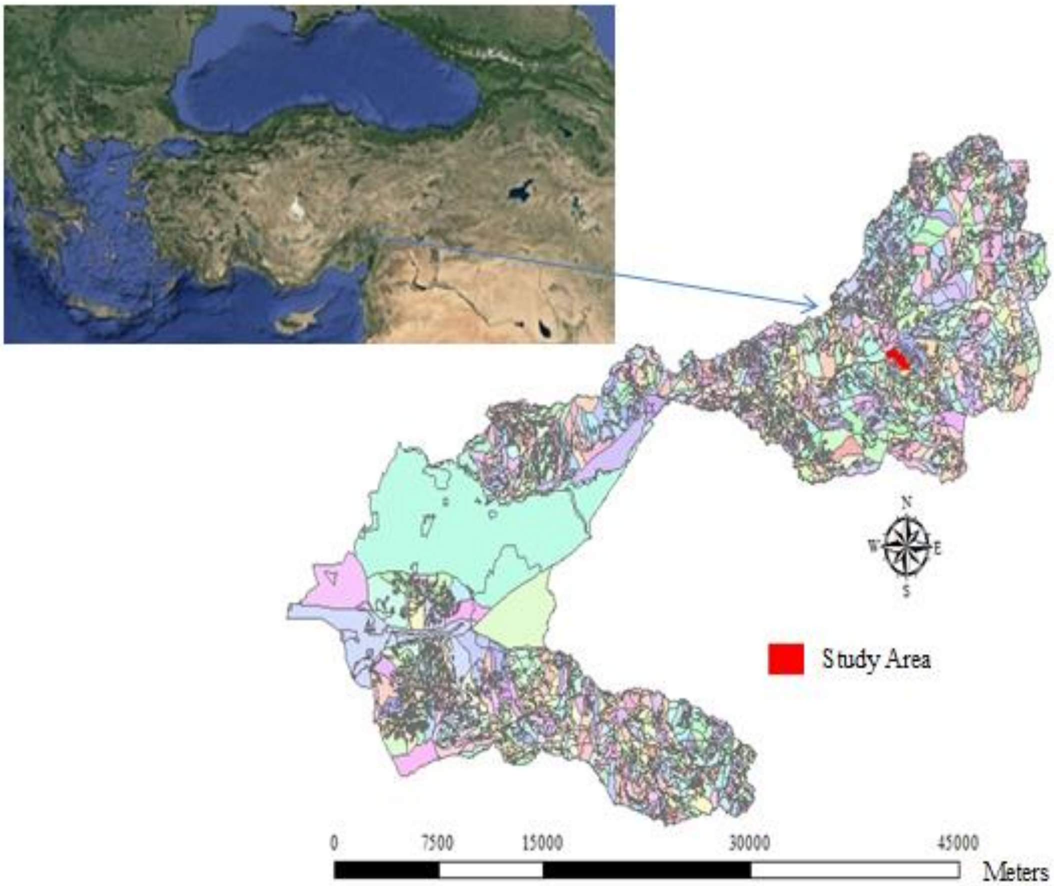

Figure 1. The study area

Figure 2. Manual loading operation

In the electric powered winch system, loading operation was carried out by party of three workers. One of the workers performs the choker setting while the other is controlling the winch by remote control devise (Figure 3). The third worker helped them directing the load to the truck and stacking the timber at the platform. The technical specifications and close view of "Biglift" winch is shown in Table 1 and Figure 4, respectively.

Figure 3. Electric powered winch loading

Table 1. Technical specifications of electric powered winch

Specifications	
Voltage	220 V
Wire length	20 meters
Pulling capacity	
Single wire (20 m)	600 kg
Double wire (10 m)	1200 kg
Weight	17 kg

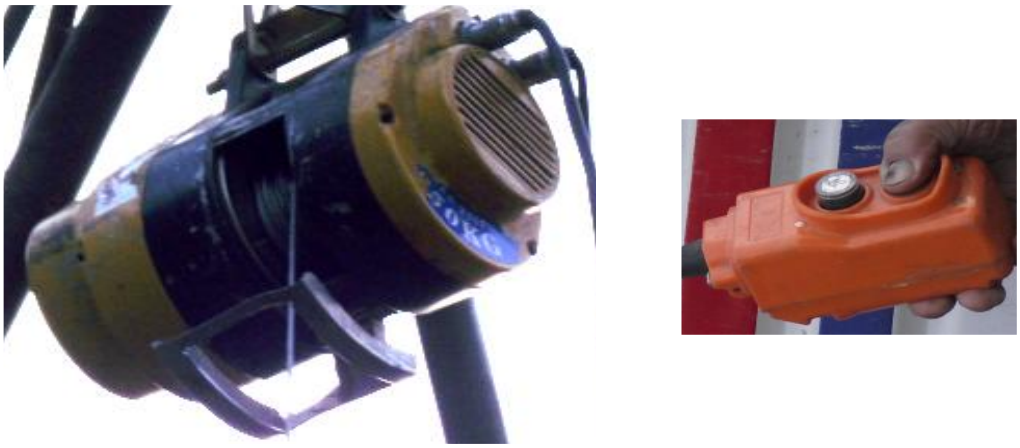

Figure 4. "Biglift" electric powered winch and remote control device

2.2. Productivity Analysis

The productivity of forest operations is generally analyzed based on time and motion studies in which the duration of work stages are measured by time recording devices (i.e. chronometer, watch, etc.) at the worksite (Szewczyk et al., 2014). In this study, chronometer was used to implement repetitive time study method which is one of the most common method for time and motion studies (Ovaskainen et al., 2004).

The main work stages considered in work cycle of manual loading system were walking to the timber on the roadside, carrying the timber next to the truck, raising the timber to the truck platform, and stacking the timber at the truck platform. In the electric powered winch system, the main work stages in the work cycle were preparation time, pulling the choker to the timber at the roadside, choker setting, pulling the timber to the truck by the winch, releasing the choker, and stacking the timber at the truck platform. During the operation, gasoline powered generator was delivering the power to the electric winch, thus, extra time spent on refueling the generator was also included into the total time. For each loading system, the timed data were measured for at least 30 work cycles and timber volume was recorded for each cycle. Then, the hourly productivity of the loading operation (m^3/hr) was computed based on the total cycle time and timber volume:

$$p = \frac{v}{t} * 60 \qquad (1)$$

v = tree volume (m^3)
t = cycle time (minutes)

2.4. Statistical Analysis

Statistical analysis were carried out in SPSS 16 software environment by considering the timber volume per cycle, total cycle time, and loading productivity. Firstly, timber volume per cycle was divided into three volume classes (low, medium, and high) and the effects of volume classes on productivity were investigated by using One-Way ANOVA method. For each loading system, the ranges of the volume classes were determined separately based on the timber volume loaded in each cycle. The correlation between timber volume per cycle and total cycle time was also investigated by using Pearson correlation analysis. Finally, linear regression analysis was used to develop a model that explains the effects of independent variable (i.e. timber volume per cycle) on the dependent variable (i.e. total cycle time).

3. Results and Discussions

3.1. Time Study and Productivity Analysis

The summary of time study data collected during manual loading operations was indicated in Table 2. It was found that total cycle time was 1.07 minutes in which stacking the timber at the truck platform was the most time consuming work stage (46%), followed by the stage of raising the timber to the truck platform. For electric powered winch system, total cycle time was found to be 2.11 minutes in which again stacking the timber at the truck platform was the most time consuming work stage (47%) (Table 3). The second most time consuming stage was pulling the timber to the truck by the winch and followed by preparation time.

Table 2. Time study data of manual loading operation (minutes)

Work Stages	Min	Max	Average	Std. Deviation
Walking to the timber on the roadside	0.09	0.14	0.12	0.01
Carrying the timber next to the truck	0.13	0.35	0.21	0.05
Raising the timber to the truck platform	0.15	0.35	0.25	0.05
Stacking the timber at the truck platform	0.18	1.12	0.49	0.26

Table 3. Time study data of electric powered winch loading operation (minutes)

Work Stages	Min	Max	Average	Std. Deviation
Preparation time	0.09	1.02	0.28	0.21
Pulling the choker to the timber at the roadside	0.05	0.08	0.06	0.01
Choker setting	0.09	0.29	0.19	0.06
Pulling the timber to the truck by the winch	0.27	0.55	0.41	0.07
Releasing the choker	0.03	0.08	0.06	0.01
Stacking the timber at the truck platform	0.25	2.00	1.00	0.41
Refueling the generator	0.00	3.40	0.11	0.62

Productivity of two loading systems including traditional manual loading system and electric powered winch system were computed by using time and motion study. The results indicated that productivity of these two systems were 3.40 m^3/hr and 4.25 m^3/hr, respectively. Even though average total cycle time of the manual loading was low, its productivity was lower than the electric powered winch system since the amount of average timber volume loaded in each cycle of winch system (0.14 m^3/cycle) was about two times more than that of manual loading system (0.06 m^3/cycle). Similar study conducted by Tunay and Varol (1999) on loading, unloading and bunching of timber showed that the productivity of manual loading was 6.59 m^3/hr with the average volume of 0.29 m^3 per cycle. Thus, timber volume per cycle is one of the main factor that affects productivity of loading operation.

3.2. Statistical Analysis Results

In the first step, effects of timber volume on productivity were investigated. The results indicated that volume classes significantly ($p<0.01$) affected the loading productivity on both loading systems. For manual loading operation, the average productivity increased from low volume (2.89 m^3/hr) class to high (3.47 m^3/hr) and medium (3.93 m^3/hr) volume classes (Table 4). For winch loading operation on the other hand, the average productivity increased from high volume (3.49 m^3/hr) class to medium (4.17 m^3/hr) and low (5.03 m^3/hr) volume classes (Table 5).

Secondly, Pearson correlation analysis was used to investigate the correlation between timber volume (independent variable) and total cycle time (dependent variable). It was found that there was a statistically significant relationship ($p<0.001$) between timber volume (X_1) and total cycle time (Y) (Table 6).

Table 4. Statistical results for manual loading system

Volume Classes	N	Average	Std. Deviation	Std. Error	95% Confidence Lower	95% Confidence Upper	Min	Max
Low	11	2.89	0.34	0.10	2.65	3.12	2.37	3.26
Medium	15	3.93	0.37	0.09	3.73	4.14	3.34	4.46
High	4	3.47	0.26	0.13	3.05	3.89	3.26	3.86
Total	30	3.49	0.59	0.10	3.27	3.71	2.37	4.46

Table 5. Statistical results for electric powered winch loading system

Volume Classes	N	Average	Std. Deviation	Std. Error	95% Confidence Lower	95% Confidence Upper	Min	Max
Low	6	5.03	0.10	0.04	4.92	5.13	4.90	5.16
Medium	20	4.17	0.41	0.09	3.98	4.36	3.70	4.98
High	4	3.49	0.41	0.20	2.82	4.15	3.15	4.04
Total	30	4.25	0.58	0.10	4.03	4.47	3.15	5.16

Table 6. Pearson correlation analysis results for both loading systems

Variables		Manual Loading Total Time (Y)	Electric Powered Winch Total Time (Y)
Volume (X_1)	Correlation Coefficient	0.95**	0.97**
	P	**0.00**	**0.00**
	N	30	30

At the finally step, models (Equation 2 and 3) were developed by using linear regression analysis to explain the effects of independent variable on the dependent variable in both systems. The results indicated that R^2 values of the regression model for manual loading and winch loading systems were 0.90 and 0.95, respectively. Table 7 indicates the results of regression models that were found to be statistically significant at the confidence level of 99%. Regression models for manual loading (Equ.2) and electric powered winch loading (Equ.3) are:

$$Y = 0.15 + 14.29X_1 \quad (2)$$

$$Y = -1.13 + 23.00X \quad (3)$$

Table 7. Regression equations

	Manual Loading	Electric Powered Winch
Constant	0.15	-1.13
X_1	14.29	23.00
R^2	0.90	0.95
Sig.	0.00	0.00

4. Conclusions

This study investigated performances of two timber loading systems including human power based manual loading and electric powered winch systems. Time and motion study method was implemented in the field to run productivity analysis. Using winch system increased the productivity of timber loading operation by about 25%. Due to higher load capacity per cycle, the productivity of the electric powered winch was higher than that of the manual loading. In Turkey, manual loading is still widely used in loading not only small size products but also large size forest products. However, manual loading may involve serious problems when there are not sufficient workforce in the region. Besides, manual loading is subject to excessive loading time, which can dramatically reduce overall efficiency of timber extraction. Thus, electric powered winch can be considered as an efficient alternative loading systems especially in areas where there is insufficient workforce.

References

Acar, H.H., 2016. A combined loading system integrated with portable winch and polyethylene chutes for loading of timber products. *Journal of the Faculty of Forestry Istanbul University*, 66(1): 329-339.

Erdaş, O., Acar, H.H., Eker, M., 2014. Forest transportation technique. Karadeniz Technical University, Faculty of Forestry, Trabzon. 504 p.

Gülci, N. 2014. Researches on precision forestry in forest planning. PhD thesis, Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Kahramanmaraş, Turkey. 264 p.

Ovaskainen, H., Uusitalo, J., Väätäinen, K., 2004. Characteristics and significance of a harvester operator's working technique in thinnings. *Int J For Eng*, 15: 67–77.

Öztürk, T., Akay, A.E., 2007. Modifying farm tractors for forest harvesting operations. International Symposium of Bottlenecks, Solutions and Priorities in the Context of Functions of Forest Resources. 17-19 October. İstanbul, Turkey.

Szewczyk, G., Sowa, J.M., Grzebieniowski, W., Kormanek , M., Kulak, D., Stańczykiewicz, A., 2014. Sequencing of harvester work during standard cuttings and in areas with windbreaks. *Silva Fennica*, 48(4): 1159-1175.

Tunay, M., Varol, T., 1999. The Investigation of loading, unloading and stacking operations in forest transportation in terms of time, productivity and cost in Western Black Sea Region. *Turkish Journal of Agriculture and Forestry*, 23(2): 441-458.