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OPERATING EFFICIENCY OF TIMBERJACK 1210B IN TRANSPORTING SOFT DECIDUOUS ROUNDWOOD

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ABSTRACT: This article presents the results of a research concerning the operating efficiency of John Timberjack 1210 B forwarder in transporting soft deciduous roundwood following a clear cut conducted by John Deere 1470D ECO III. The evaluation of operating efficiency was based on 70 transport cycles. The wood was transported over the felling site, on the trail and finally by a truck road. This article also presents an analysis of the impact of ruts on the operating efficiency of the forwarder. Rut depth ranged between 17 and 40 cm.On the basis of the results of conducted data recordings, the operating efficiency was evaluated depending on the used harvesting technology.The forwarder achieved greater efficiency in comparison to the efficiency achieved when harvesting was conducted by chainsaws. Average time needed for loading the assortments in the felling site where the harvest was conducted by the John Deere 1470D ECO III harvester is shorter than the time needed for loading the assortments in the felling site where the chainsaws were used. Also, the passage time during loading and the moving time between loading and unloading stations are significantly shorter. Greater efficiency is the result of assortment grouping when the harvester is used and reduced overlapping of assortments. These results are very important for evaluating the usage of modern technologies for forestry utilization in lowland regions of Serbia.
Keywords: forwarder Timberjack 1210 B, harvester John Deere 1470D ECO III, first phase of transport, poplar, efficiency

1 INTRODUCTION

The choice of instruments of labour in the first phase of wood transport is very important from the economic, ecological and ergonomic points of view. Factors affecting the production effects of the instruments of labour in wood transport are numerous, and their importance varies depending on the operating conditions. The operating conditions of the first phase of transport in Serbian forestry significantly differ in lowland and highland areas. The operating conditions of the first phase of transport in lowland areas are characterized by a low carrying capacity of the terrain, as opposed to the hilly and mountainous areas, where the dominant factor is the slope of the terrain and its dissected relief. Instruments of labour imposed as a logical solution in lowland areas are forwarders and tractor equipages. On the other hand, the instruments of labour used in hilly and mountainous areas, depending on the forest purpose and harvestable volume and slope, are animal-drawn carts, agricultural tractors adapted for use in forest operations, as well as forwarders specialized for such operating conditions.

The effects of the instruments of labour in the first phase of wood transport are most affected by the average transport distance and the average volume of a piece, and these are the basic inputs into the norms of work in the first phase of wood transport.

The largest quantity of assortments poplar is concentrated in the forelands of major rivers passing through the province of Vojvodina. Clear cutting is applied in poplar plantations at the end of nearly twenty-year-long production cycles.

Clear cutting is highly suitable from a technological point of view, given the possibility of larger technological freedom. Under these conditions a large amount of assortments, usually over 300 m^3/ha, is concentrated on a small area. Felling and crosscutting are mostly performed using the chain saw in the 1M + 1R organizational form of work. In addition to felling and crosscutting of assortments with the chain saw, the John Deere 1470D Eco III Harvester has been in use in the FE "Sremska Mitrovica" since 2008. After felling and crosscutting of assortments using the chain saw, evenly spaced assortments remain in the felling site. Transport of these assortments is carried out by tractor equipages or forwarders, depending on the operating conditions, type of felling and transport distance. After felling and crosscutting of assortments with a harvester, overlapping of assortments is fairly reduced. This creates an opportunity for a more efficient use of the instruments of labour used in the first phase of transportation, i.e. the assortments produced remain in small piles positioned along the row that is being cut, which provides easier forwarder manipulation and reduced passing time during loading, quicker loading and faster movement of the instrument vehicles over the felling site. This was one of the reasons to investigate the production effects of forwarders in these operating conditions.

Accordingly, the goal of this paper is to investigate the effects of production of the Timberjack 1210 B forwarder following a clear-cutting with the John Deere 1470D Eco III harvester.

The production effects of a forwarder are affected by a number of factors, including: the intensity of felling, field conditions, operator skills (Lageson 1997, Karha 2003, Poršinsky 2005) and the silvicultural treatment (Eliasson, 2000, Glode and Sikstrrom, 2001, *et al.).*

2 METHOD AND RESEARCH OBJECT

This study was performed in the areas of FE "Sremska Mitrovica" , FA “Klenak” and FMU "Senajske bare-Krstac", compartment 26 (Fig. 1 and 2).

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Figure 1: Loading of assortments

Figure 2: Ruts

The recording was performed in November and December of 2009. A total of about 70 transport cycles were recorded.

The transport of wood was carried out in winter conditions. During the recording period, the weather was changeable with rainy and snowy intervals. A 5-10 cm high snow cover was formed. The average air temperature during the recording period was between 2 and 17 º C.

The soil types were III / 1 and IV/15. Ruts with a depth of 17 to 40 cm were formed during wood transport, depending on the recording period (Fig. 2). Rut depth was measured for each transport cycle at three different measurement points.

The recording was performed using photochronometry, i.e. work time study was applied. The time flow method was employed to measure the duration of the operations using a chronometer with an accuracy of up to one second.

In the course of forwarder application the following operations were recorded: *manipulation at the temporary landing, drive to uplift the load, manipulation in the felling site, loading of wood assortments, passing during loading, and return from the felling site to the unloading station*. All downtime periods during operation were recorded. The assortment landing was located on a truck road.

The number of transport cycles needed for the analysis was calculated using variation statistics. The Statistics 6.0 statistical program was used to statistically process the data, i.e. this paper employs conventional statistical and mathematical methods (regression, correlation, descriptive statistics, etc.).

3 RESEARCH RESULTS

The total volume of timber transported during the recording period was 899 m^3, i.e. the average volume of a transport cycle was 13.0 m^3. Timber transport by the Timberjack 1210 B forwarder in the studied conditions was carried out on roads that belonged to very different categories. Following transport over the felling site, the assortments were transported by a dirt road and finally by a hard (macadam) road. The unloading of assortments was performed in two piles for sorting purposes.

The average transport distance by dirt road was 492m, and the average speed at which the forwarder moved amounted to 63.5 $m\cdot min^{-1}$. The average transport distanc e over the felling site was 163m at the average speed of 42.9 $m\cdot min^{-1}$.

The duration of loading and unloading is directly dependent on the average volume of a piece and load volume $t_{ui} = f(m)$.

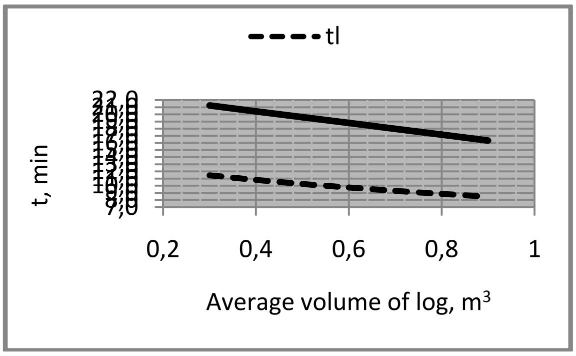

Figure 3: Correlation between loading and unloading time and the average volume of a piece

The loading time decreases with an increase in the average volume of a piece (R-0.167, p-0.164) (Fig. 3).

The correlation between the loading time and the average volume of a piece is presented by the formula $t_l = \frac{1}{0,072+0,051\cdot m}$, and the sum of loading and unloading time by the function $t_{lu} = 23,7 - 8,17 \cdot m$.

The time of movement of a transportation means depends on the terrain characteristics, the speed of that transportation means and the transport distance $t_s = f(V,S)$.

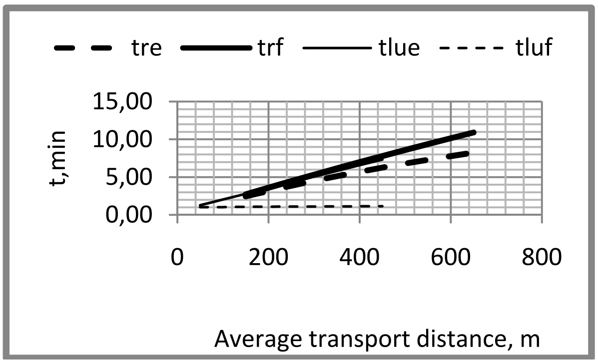

Figure 4: Correlation between forwarder movement time and average transport distance

The average movement time of a loaded transport vehicle on all categories of roads is shorter than the time achieved by an empty transport vehicle. The difference is most pronounced in the movement over the felling site (Fig. 4).

The correlation between the average time spent on the movement of an empty forwarder over the felling site and the average transport distance is represented by the linear regression equation $t_{lue} = 0,527 + 0,0151 \cdot S$, (R-0.882, p-0.000), and the full rounds, i.e. the same correlation for a loaded forwarder by the regression equation, $t_{luf} = 1,025 + 0,022 \cdot S$, (R-0.913, p-0. 000).

The correlation between the average time spent on the movement an empty forwarder on a dirt road and the average transport distance is represented by the equation $t_{re} = \dfrac{1}{0,035 + \dfrac{56,1}{S}}$, (R-0.723, p-0.000), and the full rounds, i.e. the same correlation for a loaded forwarder by the regression equation, $t_{rf} = \dfrac{1}{0,0093 + \dfrac{53,5}{S}}$, (R - 0.770, p-0. 000).

The participation of downtime in the total forwarder work time amounted to 1.5 min / round. The low percentage of downtime at work is the result of several factors, including: the skills of a forwarder driver, good organization of the field work, proper functioning of machinery, field conditions, etc. (Danilovic, 2010). The basic norms of work under the studied conditions were calculated on the basis of the performed recordings.

The basic norms are the following:

- Average speed on a dirt road (V_z) 63.5 $m \cdot min^{-1}$
- Average speed on a hard truck road (V_k) 83.3 $m \cdot min^{-1}$
- Average speed in the felling site (V_s) 42.9 $m \cdot min^{-1}$
- Manipulation time (t_m) 3.9 $min \cdot turi^{-1}$
- Loading time (t_u) 0.88 $min \cdot m^3$
- Unloading time (t_i) 72 $min \cdot m^3$
- Downtime(t_z) 1.5 $min \cdot turi^{-1}$
- Average volume of a round (Q) 13.0 $m^3 \cdot turi^{-1}$

The share of additional time that was used to calculate the work norms in this study was 18%.

In this study, the distance over the felling site was taken as the calculated transport distance. The coefficients for converting the distance on a dirt road and hard truck road into the distance over the felling site were k_z- 0.68 and k_k-0.52, respectively, and the calculated transport distance under the conditions that were the object of this research was 547.5 m.

The daily costs of operation of the Timberjack 1210 B forwarder were calculated using standard calculations, and they amounted to € 370.1·day^{-1}.

The purchase price of a forwarder is 285,000 EUR, and the amortization period is 5 years at the annual usage of 1,600 operating hours and the fuel price of 1.31 EUR·L^{-1}.

The average output achieved by the Timberjack 1210 B forwarder was 92.8 $m^3 \cdot day^{-1}$. The unit costs, which amounted to 3.99 euros • m^{-3}, were calculated on the basis of direct labor costs and actual performance.

These costs were directly correlated with the average transport distance and the average volume of a piece. Figure 5 shows the unit costs in correlation with the transport distance and the volume of a piece.

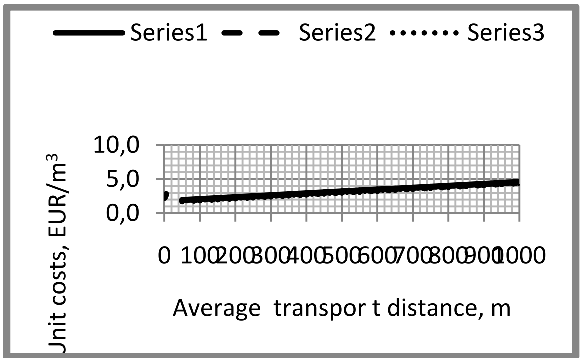

Figure 5: Correlation between unit costs, transport distance and the volume of a piece

Rut depth was measured at four points, i.e. two on the IV/15 soil type and another two on the III/1 soil type. On the III/1soil type, rut depth was measured at distances of 120 m and 300 m from the landing, while on the IV/15 soil type it was measured at distances of 220 m 435 m from the landing. The measurement was conducted in November, at the air temperatures ranging from 6 to17 º C and in December, at the air temperatures ranging from 2 to 6 º C. In addition, out of the six days in December three were characterized by a relatively light rainfall. Rut depth was measured in the same place after each forwarder pass. With the growing number of repetitions the number of cycles and rut depth increased. Maximum rut depth was 40 cm at both measurement points. This depth was measured on the III/ 1 soil type in rainy weather, after 49 cycles along the same rut, while on the IV/15 soil type the measured depth amounted to 38 cm and 35 cm, at the first and second measurement points, respectively. This interval was followed by a chilly period with a decrease in temperature. Movement of the forwarder changed, and new measurements were performed at the same distances from the landing. After 14 transport cycles, the maximum rut depth was about 34 cm on the III/1 soil type, and about 30 cm on the IV/15 soil type.

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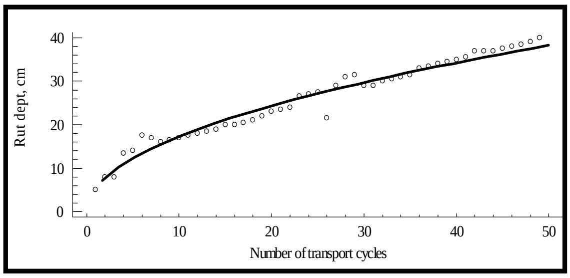

Figure 6: Correlation between rut depth and the number of transport cycles

Along with the growing number of repetitions or cycles, rut depth also increased. The correlation between the number of transport cycles and rut depth is represented by the function $D_r = 5,55 \cdot N^{0,493}$, (R-0. 981, p-0. 000) (Fig. 6).

4 DISCUSSION

The results of this study indicate that the Timberjack 1210 B forwarder achieves great outputs under the investigated conditions, and that its effects are greater than the effects achieved by this or similar forwarders realized when performing felling with the chain saw. The reason for this could be the fact that the overlapping of assortments in felling and crosscutting with the harvester was reduced, which enabled shorter duration of forwarder loading. In addition, there are fewer obstacles in the felling site, causing a lower coefficient of bypassing an obstacle, i.e. shorter transport distances. The speed of movement of empty and full forwarders over the felling site is higher than the maximum speed achieved by the same vehicles in the felling sites where felling and crosscutting were performed using the classical procedure, especially when long cordwood is not produced. In that case, the branches are scattered across the felling site which hinders forwarder movement. However, under the conditions that characterized this research, the branches were grouped in the middle of a row and they did not represent a major obstacle for the forwarder. At higher humidity these branches have a positive effect on the work of a forwarder, because they prevent the formation of large ruts. The efficiency of this instrument of labour was reflected in the high outputs that resulted from a small share of downtime, good manipulation skills, etc. Similar conclusions were obtained in previous studies of the Timberjack 1210 B and John Deere 1710D forwarders (Jezdić et al, 1995, Jezdić et al., 1999, Poršinsky 2005). Most of the paper authors point out that the key factors affecting the production effects are the transport distance, the average volume of a piece and field operating conditions. In lowland areas the chosen instruments of labour in the first phase of roundwood transport can be tractor equipages or forwarders. From the economic point of view, tractor equipages are preferable at larger transport distances. The limit distance of the cost-effective application of a forwarder instead of a tractor equipage varies widely, due to its dependence on several factors. This limit distance is significantly shorter under favourable operating conditions, than under unfavourable ones, characterized by a small carrying capacity of the terrain, large amount of shrubby vegetation, etc. (Danilovic 2010).

According to previous research the limit distance to which it is economically viable to use a forwarder is about up to 1 km, or often much less. In Serbia, the openness of forests with a network of roads is insufficient in lowland areas, which directly affects the applicability of forwarders. Hence, the presence of tractor equipages is higher. The situation is somewhat different in the FE "Sremska Mitrovica", where the average transport distance is shorter than 500 m, which imposes the application of forwarders as a logical solution. Under these conditions, it is necessary to pay special attention to the size of the chosen forwarders. It is economical to apply small forwarders for thinning, preferably without a thrust washer, and in major cuttings medium and heavy forwarders should be used (Danilovic 2010). At very difficult terrains, with low carrying capacity, it is necessary to mount half-tracks. For example, half-tracks are often used year round in Finland, regardless of field conditions (Suvinen, 2006). The advantage of half-track application is reflected in the reduction of pressure on the surface, due to the larger contact area between the tires and the ground.

Due to the low density of forest roads in the lowland areas of Serbia tractor equipage will continue to be a very important instrument of labour in roundwood transport.

The annual forwarder output under the conditions that are typical for this study is approximately 20,000 m^3, which means that the transport of technical roundwood from regular harvesting of poplar plantations that is carried out by harvesters can be performed by two forwarders. Good organization of work is necessary if that is to be achieved.

There was little difference regarding certain correlations between the effects of forwarders observed in this study and those obtained by other authors (Ghaffarian *et al.* 2007, 1999, etc. Jezdić, Danilovic, 2010), except to the extent dictated by terrain conditions.

The average speed of a forwarder in the felling site and on a soft summer road obtained in this study is slightly higher than the speed obtained in the research of transport of soft broadleaf roundwood using the Timberjack 1210 B Forwarder under similar operating conditions (Jezdić et al., 1999). Also, loading and unloading time expressed per piece is shorter than the time obtained for the Timberjack 1210 B forwarder.

5 CONCLUSIONS

The following conclusions can be reached on the basis of the analysis performed:

- Vehicle loading and unloading times are directly correlated with the average volume of a piece and the volume of load, and this correlation is linear;
- The correlation between the average time spent on empty and full forwarder movement over the felling site and the average transport distance is linear;
- The movement of forwarders over the felling site where felling was performed with a harvester is much easier compared to their movement over the felling site, where felling was performed using the chain saw, primarily due to the reduced overlapping of stems during felling;
- Full utilization of a forwarder capacity, which can be achieved by good organization of work, and hiring drivers trained for operation and maintenance of these vehicles, will increase production effects;

- The construction of forest roads will reduce the average transport distance and create conditions for an economic use of forwarders;
- In areas unprotected from floods, with pronounced depression and low carrying capacity, the forwarder is the best choice from the technical, economic and environmental points of view, and
- The correlation between the number of transport cycles and rut depth is represented by the power function model.

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