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FUEL CONSUMPTION IN THE TRANSPORT OF TECHNICAL BROADLEAF ROUNDWOOD IN LOWLAND AREAS

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Abstract: This paper presents the results of an analysis of fuel consumption in the transport of technical roundwood of soft broadleaves from the felling site to a roadside landing using forwarders and tractor assemblies. The research was performed in various operating conditions in the area of FE "Banat" Pančevo. On the basis of the results of the analysis of variance, the data recorded in a variety of conditions were grouped. In addition, the dependence of fuel consumption on the average volume of tour was estimated. The results of the conducted analysis indicate that operating conditions sgnificantly affect fuel consumption of the investigated vehicles. The elements of statistical analysis of the dependence of fuel consumption on the volume of load indicate that an increase in load causes increased fuel consumption per unit of production. Having in mind the results of the analysis of variance, unique norms of fuel consumption were adopted for practical purposes.

The highest average consumption (1.21 L / m^3) was achieved by a tractor assembly (Same Laser 130 tractor and Imako TP12 trailer with a Loglift 61F hydraulic crane), while significantly lower consumption was achieved by a John Deere 1210E forwarder (1.06 L / m^3). In favourable operating conditions, consumption of the forwarder was about 0.9 L / m^3.

Key words: fuel consumption, norms, technical poplar roundwood, transport, forwarder, tractor assembly

INTRODUCTION

In order to become familiar with the nature and structure of the production process, and successfully monitor and manage this process, it is necessary to know the consumption of all materials. This applies to almost all fields of production, including forestry. In forestry production this especially applies to fuel and lubricant consumption, as the consumption of materials significantly affects the costs of timber production (Bajić and Danilović, 1999).

The significance of this issue is even greater if we consider the fact that the demand for energy resources in the world is great and that due to their limited amounts their price will grow in the future, and as a result cause an increase in the costs of production.

Losses arising from irrational energy consumption cannot be compensated by increasing outputs of the production process, and it is therefore necessary to establish appropriate norms of energy consumption and monitor their application (Danilović et al. 2014).

Fuel consumption is important both from the economic and the environmental aspects. In the past few decades, and especially in the past two decades, we have been witnessing a growing concern for the environment and the negative effects that result from the burning of fossil fuels. Fuel consumption is an important item in the calculation of costs of the means of transportation, and consequently it affects unit operating costs. Fuel consumption can be used as an estimator for the machines' operating costs (Sundberg and Svanqvist, 1987).

The fuel consumption of machines operating in forestry is affected by a large number of factors. It is most affected by construction of the engine, engine type and maintenance of the machine, the operator's skills and operating conditions. Most of the machines that are nowadays used in forestry have diesel engines. Diesel engines, like gasoline engines, are characterized by a combination of a large number of engine revolutions with a small output torque which increases fuel consumption. Therefore, the operator's skill is an extremely important factor in fuel consumption.

However, movement of the means of transportation in different operating conditions is accompanied by constant changes in the speed of movement, resistance and obstacles on roads, which also affects fuel consumption. According to Rebula (1989), skidding distance, slope of the terrain and load volume have the highest impact on fuel consumption during timber skidding.

Reduced fuel consumption per unit of production is a key issue in the economics of forest products and approaching to more sustainable forest management practices (Nordfjell et al., 2003). The share of fuel costs in the total costs is quite different depending on various conditions.

According to Favreau and Gingras (2007) fuel costs account for 10% of the total cost if the assortments are produced by the CTL method, while Johansson (2001) argues that it accounts for 20% of direct costs of felling in the stand where final felling was completed.

The share of fuel costs in the total costs depends on the stage of the technological process. According to Grecs (1986) the share of fuel costs in total energy consumption in the phase of felling and wood assortment processing is 7%, 43% at the skidding stage, 26.6% during loading and transport, 12% in the construction and maintenance of forest roads and 4% in the activities of forest management.

Due to a large number of factors that influence the machine over time, fuel consumption is also changed. Therefore, it is necessary to continuously monitor fuel consumption and find new ways reduce fuel consumption.

The main objective of this research is to determine fuel consumption of the equipment used for timber extraction of technical broadleaf roundwood in different operating conditions.

In addition to that, one of the objectives is to determine the degree of dependence of fuel consumption on the volume of load in different operating conditions. The final results of the research are established norms of consumption, which are necessary for the planning of these works.

The norms of consumption for the equipment were determined individually for the operating conditions which were significantly different.

METHOD

The research was performed within the project "Standardization of forestry works with special emphasis on the selection of optimal technologies of work in the SE" Vojvodinašume".The recording of fuel consumption of a John Deere 1210E (A) forwarder, a tractor assembly consisting of a Same Laser 130 tractor and Imako TP12 trailer with a Loglift 61F (b) hydraulic crane and a tractor assembly made up of a Same Silver 105 tractor and an Imako TP12 trailer with a Loglift 61F (C) hydraulic crane was carried out in the FE "Banat" Pančevo as part of regular activities in 2011, 2012 and 2014.

Technical characteristics of the investigated equipment are shown in Table 1.

The studied John Deere 1210E forwarder was produced in 2009, whereas the year of production of the tractor assemblies was 2006, which means that this equipment was in the depreciation period. The forwarder and tractor assemblies were driven by experienced drivers in all sample plots.

Table 1. Technical characteristics of the investigated equipment

<table>
<tr><th colspan="2" rowspan="2"></th><th rowspan="2">Type of Engine</th><th>A</th><th>B</th><th>C</th></tr>
<tr><th>Euro III - Turbo</th><th>Euro I – Turbo</th><th>Euro II</th></tr>
<tr><td colspan="2" rowspan="4">ENGINE</td><td>Power [kW/KS]</td><td>136 (183)</td><td>95 (130)</td><td>77,2 (105)</td></tr>
<tr><td>Cylinder capacity [L]</td><td>6,8</td><td>6,2</td><td>6,0</td></tr>
<tr><td>Wheelbase distance [cm]</td><td>510</td><td>280</td><td>264</td></tr>
<tr><td>Mass [kg]</td><td>16200</td><td>5170</td><td>4250</td></tr>
<tr><td colspan="2" rowspan="2">Tires</td><td>Front</td><td>34-14</td><td>14,9-30</td><td>380/70R28</td></tr>
<tr><td>Rear</td><td>26,5-20</td><td>18,4-38</td><td>480/70R29</td></tr>
<tr><td rowspan="6">TRAILER</td><td colspan="2">Type</td><td>-</td><td colspan="2">Imako TP 12</td></tr>
<tr><td colspan="2">Length [mm]</td><td>4.500</td><td colspan="2">4.600</td></tr>
<tr><td colspan="2">Width [mm]</td><td>2.700</td><td colspan="2">2.500</td></tr>
<tr><td colspan="2">Wheels</td><td>Wheels with single tires</td><td colspan="2">Wheels with single tires</td></tr>
<tr><td colspan="2">Clearance of trailer on wheelbase [mm]</td><td>605</td><td colspan="2">456</td></tr>
<tr><td colspan="2">Load capacity [t]</td><td>13</td><td colspan="2">12</td></tr>
<tr><td rowspan="8">HYDRAULIC CRANE</td><td colspan="2">Hydraulic crane</td><td>Cranab CF7</td><td colspan="2">Lolift 61 F</td></tr>
<tr><td colspan="2">Gross lifting capacity [kNm]</td><td>125</td><td colspan="2">91</td></tr>
<tr><td colspan="2">Manual outreach [m]</td><td>10</td><td colspan="2">7,2</td></tr>
<tr><td colspan="2">Crane mass [kg]</td><td></td><td colspan="2">1.125</td></tr>
<tr><td colspan="2">Stabilizers</td><td>-</td><td colspan="2">Spider, coupling</td></tr>
<tr><td colspan="2">Total crane mass [kg]</td><td></td><td colspan="2">1525</td></tr>
<tr><td colspan="2">Slewing angle [°]</td><td>380˚</td><td colspan="2">380°</td></tr>
<tr><td colspan="2">Management system</td><td>From the forwarder cabin</td><td colspan="2">From the tractor cabin</td></tr>
</table>

The operating conditions differed in terms of terrain dissection, share of undergrowth, soil moisture, the presence of obstacles in the felling site (forest residues, stumps, etc.), as well as the degree of felling site arrangement, i.e. whether the collection of forest residue and stacking of cordwood had been previously performed.

In all sample plots (felling sites) logging was performed with a chainsaw, and assortments were produced using the assortment method.

The landing for wood assortments was either on a truck road or on a riverbank, and the transport was carried out through the felling site,via earthroad and a forest road with a macadam carriageway.

The recording of fuel consumption during the transportation of technical roundwood of soft broadleaves with the forwarder was conducted in eleven felling sites (I- XI) (Table 2).

In four felling sites, the recording of fuel consumption was carried out for a tractor assembly made up of a Same Laser 130 tractor and an Imako TP12 trailer with a Loglift 61F hydraulic crane during the transport of technical soft broadleaf roundwood. In three felling sites, fuel consumption was recorded for a tractor assembly made up of a Same Silver 105 tractor and an Imako TP12 trailer with a Loglift 61F hydraulic crane during the transport of technical roundwood of broadleaves (Table 3).

Table 2. A table of major basic characteristics of the felling sites.

Felling site		I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Age of the plantation		22	25	25	24	25	25	25	20	27	27	24
FMU		2806	2806	2806	2806	2804	2804	2806	2806	2801	2801	2806
Compartment		32/e	52/b	52/b	35/d	75/a	75/a	85/c	47/e	19/e	19/e	51/f
Tree species		I-214	I-214	I-214	I-214	I-214	I-214	P. delt.	I-214	I-214	I-214	I-214
Area (ha)		9,32	9,28	9,28	5,80	32,19	32,19	410	463	1383	1383	12,16
Planting spacing		5×5	5×5	5×5	6×4	6×4	6×4	5×5	5×5	6×3	6×3	5×5
V (m^3/ha)		170	380	380	364	428	428	327	110	523	523	432
Number of trees per hectare (N/ha)		248	244	244	264	278	278	285	360	290	290	380
Soil		71	71	71	84	81	81	84	14	84	84	51
Forest residue[1]		+	+	+	±	-	-	-	±	-	-	-
Rut depth[2]	S	0	10	5	35	15	15	0	0	8	0	30
	MP	0	0	5	0	0	0	0	0	-		
Type of assortment[3]		T, VC	T, VC	T, VC	T,VC, M	T, VC	T, M	T, VC, M	T, VC, M	T, VC, M	T, VC, M	T, VC, M
Number of tours	T	4	-	-	-	-	-	-	-	-	-	17
	VC	1	-	-	-	-	-	-	-	-	-	6
Unloading[4]		KS	KS	KS	KS	KS	KS	KS	KS	OR	OR	KS
Protected (Z), Flood-prone (P)		Z	Z	Z	P	P	P	P	P	P	P	Z

[1] Forest residue: collected (+), non-collected (–), partly collected (±)
[2] Rut depth: felling site (S), soft road (MP)
[3] type of assortment: logs(T), long cellulose wood (VC), meter wood (M)
[4] Unloading: truck landing (KS), riverbank (OR)

Table 3. Table of major characteristics of the felling sites

Felling site		I	II	III	IV	I	II	III
Equipment				B			C	
Age of plantation		25	22	22	47	25	23	28
FMU		2804	2806	2806	2806	2804	2806	2804
Compartment		75/a	65/c	65/c	75/c	75/c	65/l	26/a
Tree species		I-214	P. delt.	P. delt.	I-214	I-214	P. delt.	I-214
Area (ha)		32,19	48	48	2,14	32,42	1,63	15,55
Planting spacing		6x4	5x5	5x5	5x5	5x5	5x5	6x6
V (m^3/ha)		428	128	128	358	436	142	426
Number of trees per hectare (N/ha)		278	255	255	92	253	388	180
Soil		81	71	71	84	84	71	84
Forest residue		-	-	-	-	-	-	-
Rut depth	S	15	0	0	30	0	0	15
	MP	0	0	0	10	0	0	15
Type of assortment produced		T, M	T, VC	T, VC	T, VC	T, M	T, VC	T, M
Number of tours	Logs, (tour)			3			3	
	Multimeter cellulose wood (tour)			1			1	
Unloading		KS	KS	KS	OR	KS	KS	KS
Plantation position (Protected (Z)/ Flood-prone (P))		P	Z	Z	P	P	Z	P

The recording of fuel consumption was conducted by the method of tank refueling. Tank refuelling was performed on every work day after work. Before starting work on the next day, the fuel in the tank was controlled. Fuelling up to a full tank after the completion of work, as well as the control of the level of fuel were carried out on flat ground to avoid measurement errors.

The control of proper work of the equipment was carried out regularly with an emphasis on the proper functioning of the counter of engine operation hours.

The number of realized transport cycles during which fuel consumption of the equipment was recorded is shown in Table 4.

Table 4. Number of transport cycles

Operating conditions		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	∑
Number of transport cycles	A	21	31	18	24	31	16	54	7	55	12	23	292
	B	32	31	8	14	-	-	-	-	-	-	-	85
	C	12	16	8	-	-	-	-	-	-	-	-	36

The recorded data were analyzed and processed using standard mathematical and statistical methods (descriptive statistics, regression, correlation, analysis of variance). The dependence of fuel consumption (dependent variable) on the volume of load (independent variable) was performed using the mathematical-statistical method of regression analysis.

Fuel consumption was also determined both per unit of volume of transported wood assortments and per hour of tractor operation.

RESEARCH RESULTS

The data recorded individually by felling sites for the John Deere 1210 E forwarders that were the subject of study are shown in Table 5. The data on the amount of assortments are given in a summarized form. The average fuel consumption is expressed per hour and unit of volume. Consumption can also be shown per norm day, considering that for all conditions (Table 5) work norms of the means of transportation were recorded in addition to the recording of fuel consumption.

Table 5. Average fuel consumption of the John Deere 1210 forwarder in the investigated operating conditions

Felling sites (OP)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Forwarder John Deere 1210E											
Total volume of transported wood assortments, m^3	253,1	443,4	235,2	329,6	433,6	220,1	703,8	95,7	980,4	115,1	293,0
Average volume of tour, m^3/tour	12,1	14,3	13,1	13,7	14,0	13,8	13,0	13,6	14,1	9,4	12,8
Hours of tractor operation performed, h	22	36	17	31	34	23	51	8	61	10	24
Fuel consumption, L	269,5	517,0	204,0	465,0	451,0	316,0	635,0	123,0	823,0	122,0	318,0
Fuel consumption,, L/h	12,3	14,4	12,1	15,2	13,5	13,8	12,6	15,4	13,8	12,2	13,3
Fuel consumption,, L/m^3	1,1	1,2	0,9	1,4	1,0	1,4	0,9	1,3	0,9	1,1	1,1

OP-sample plot

Results of the analysis of variance (F-19.9; p-0.000) indicate that between the average fuel consumption of the John Deere 1210E forwarder expressed in L/m3 in different operating conditions there are statistically significant differences at the 95% confidence level. Four groups of conditions can be distinguished on the basis of the results of an LSD test. Average fuel consumption in L / m3, is not statistically different among the operating conditions in felling sites IV, VI and VIII (first group), I, II, V, X and XI (second group), III and VII (third group), whereas the operating conditions in felling site IX stand out particularly.

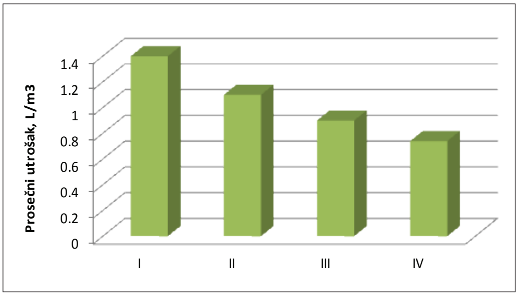

Figure 1. Average fuel consumption for grouped operating conditions

Tables 6. and 7. show the data of measurement of fuel consumption and volume of assortments transported during recording in different operating conditions.

Table 6. Average fuel consumption in the investigated operating conditions

Felling sites (OP)	I	II	III	IV
Tractor assembly (tractor Same Laser 130, trailer Imako TP 12, hydraulic crane Loglift 61F)				
Total volume of transported assortments, m^3	379,3	326,7	47,5	152,4
Average volume of tour, m^3/tour	11,8	10,5	5,9	10,9
Hours of tractor operation performed, h	47	42	12	26
Fuel consumption, L	386	373	87	211
Fuel consumption, L/h	8,4	8,9	7,3	8,3
Fuel consumption, L/m^3	1,0	1,2	1,8	1,4

OP-sample plot

Table 7. Average fuel consumption in the investigated operating conditions

Felling sites (OP)	I	II	III
Tractor assembly (tractor Same Silver 105, trailer Imako TP 12, hydraulic crane Loglift 61F)			
Total volume of transported assortments, m^3	129,9	186,6	96,2
Average volume of tour, m^3/tour	10,8	11,7	12,02
Hours of tractor operation performed, h	15	20	13
Fuel consumption, L	138	194	104
Fuel consumption, L/h	9,2	9,7	8,4
Fuel consumption, L/m^3	1,1	1,0	1,08

Average fuel consumption of a tractor assembly made up of a Same Laser 130 tractor and an Imako TP 12 trailer with a Loglift 61F hydraulic crane, expressed in L / m3, in conditions that were the subject of this research is statistically significantly different (F-47.4; p-0.000) observed at the 95% confidence level. There are no significant differences (F 1.52; p-0.00) between the average fuel consumption expressed in L/ h.

There are no statistically significant differences (F 0.56; p-0.599) observed at the 95% level of confidence among the levels of average fuel consumption in L/m3 in different operating conditions of the investigated tractor assembly made up of a Same Silver 105 tractor and an Imako TP12 trailer

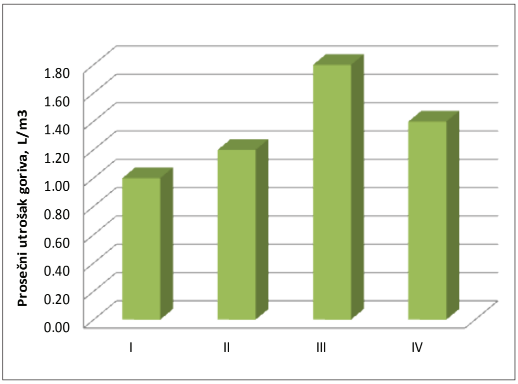

Figure 2. Average fuel consumption in different operating conditions

with a Loglift 61F hydraulic crane. The average fuel consumption is 1.06 L/m^3 or 9.08 L/h.

There are statistically significant differences between the average fuel consumption of a forwarder and a tractor assembly made up of a Same Laser 130 tractor and an Imako TP12 trailer with a hydraulic crane Loglift 61F, expressed in L/m^3 in similar operating conditions (F-63.2; p-0.00). However, there are no statistically significant differences between the assemblies in similar operating conditions (F-0.85; p-0.393).

Fuel consumption expressed in L/m^3 decreases with an increasing volume of load in all felling sites taken as representative for this analysis (Figure 3).

The average fuel consumption expressed in L/m^3 in different operating conditions at a constant mean transport distance decreases with an increasing volume of tour. Therefore, it is very important that an optimal load is formed during transport. Otherwise, the average fuel consumption may be increased.

Analytical expressions of functions of the dependence of fuel consumption on the volume of load during the transport of soft broadleaf logs are shown in Table 8.

On the basis of the determination coefficient, it was found that fuel consumption is affected by other factors in addition to the volume of load, especially in the case of assembley consisting of a Same Silver 105 tractor and an Imako TP 12 trailer with a Loglift 61F hydraulic crane.

The analysis of all data recorded for different operating conditions, revealed that the forwarder spent 13.4 L per hour of work on average. The tractor assembly made up of a Same Laser 130 tractor and an Imako TP 12 trailer with a Loglift

Table 8. Regression equations of the investigated dependences

A			B	C
A_{II}	**A_{VII}**	**A_{IX}**	**B_{III}**	**C_{IV-VI}**
$U_g = \frac{1}{(0{,}527+0{,}023\cdot Q)}$	$U_g = -0{,}590+\frac{19{,}42}{Q}$	$U_g = \frac{1}{\left(4{,}7-\frac{48{,}9}{Q}\right)}$	$U_g = \frac{1}{(-1{,}44+0{,}21\cdot Q)}$	$U_g = \frac{1}{\left(1{,}2-\frac{2{,}89}{Q}\right)}$
R-0,457; S_r-0,060; p-0,362	R-0,943; S_r-0,039; p-0,021	R-0,760; S_r-0,131; p-0,028	R-0,544; S_r-0,053; p-0,163	R-0,306; S_r-0,043; p-0,423

Q-average tour volume, Ug-fuel consumption

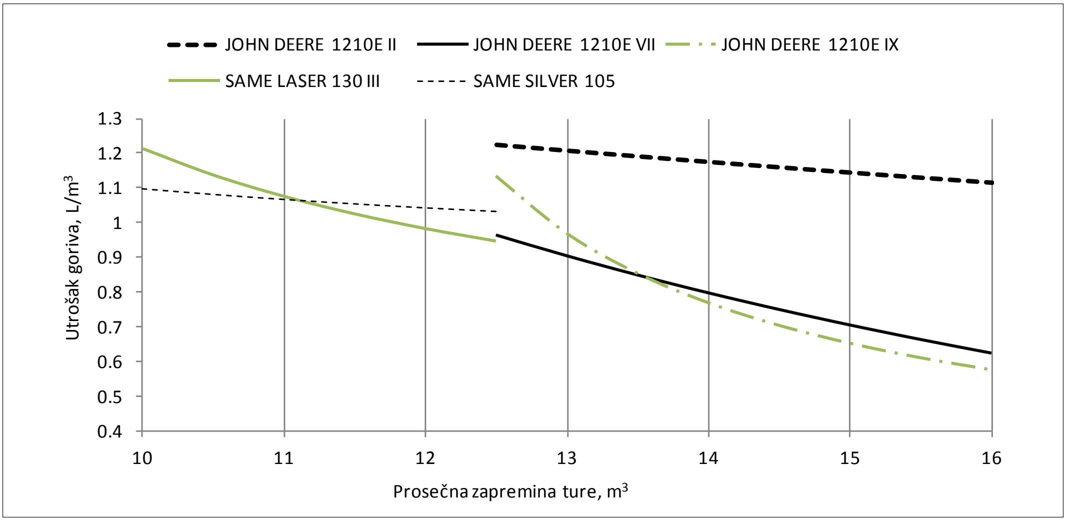

Figure 3. The dependence of fuel consumption on the volume of load

61F hydraulic crane spent an average of 8,5 L per hour, while a tractor assembly made up of a Same Silver 105 tractor and an Imako TP 12 trailer with a Loglift 61F hydraulic crane consumed 9.2 L per hour of work. On the basis of the results of the analysis of variance, it can be concluded that there are significant statistical differences (F-80.5; p-0.000) between the forwarder and tractor assemblies, while there are no statistically significant differences among the assemblies. When the consumption in L/m^3 is concerned, the highest average consumption (1.21 L/m^3) was achieved by a tractor assembly made up of a Same Laser 130 tractor and an Imako TP 12 trailer with a Loglift 61F hydraulic crane.

DISCUSSION

The movement of vehicles is accompanied by constant changes of speed and resistance, and consequently changes in fuel consumption. The fuel consumption of forest machines is affected by many factors, including skidding distance and the average volume of load. The increase in skidding distance decreases productivity and increases fuel consumption.

The average fuel consumption per productive machine hour in the studied operating conditions of forwarders, ranged from 12.1 to 15.4 L/h, while according Nordfjell et al. (2003), fuel consumption of forwarders varied between 8.3 to 15.7 L/PMH (productive machine hour) for different work elements. Fuel consumption in the transport of logs and long roundwood with the assembly Same Laser 130 tractor, Imako TP 12 trailer and Loglift 61F hydraulic crane was lower ranging from 7.3 to 8.9 L/h and the transport of logs and long timber with a tractor assembly Silver 105 tractor, Imako TP 12 trailer and Loglift 61F hydraulic crane ranged from 8.4 to 9.7 L/h.

Fuel consumption of an adapted farm tractor is lower than the consumption of a tractor assembly. This is supported by a research of Rebula (1989), which argued that fuel consumption of adapted IMT tractors at empty travel ranged from 3.90 to 6.55 L / h and for loaded travel from 3.91 to 10.47 L/h.

According to Nordfjell et al. (2003), forwarders (weight 16-20 tonne) consumed on average 0,62 L/m^3 (sawlogs and pulpwood, 318 m average extraction distance) for final felling. In our research, fuel consumption during transportation of the technical roundwood of broadleaves ranged from 0.9 to 1.4 L/m^3. The reason for the higher fuel consumption in our research is reflected in the much greater transport distances and unfavorable operating conditions.

Movement of the means of transportation in severe working conditions requires a slower speed, which usually means using a low gear for tractors or low speed for forwarders. This affects the degree of utilization of the engine power and therefore fuel consumption. For this reason, the impact of work organization on the rational use of fuel is multifold. Fuel consumption can be influenced as early as in the phase of selecting the type of vehicle and its load capacity. Continuous control of fuel consumption can affect the rational use of fuel, and thus the reduction in the costs of production.

CONCLUSIONS

On the basis of the conducted research, analyses of the data recorded, data processing and statistical methods, the following conclusions can be drawn:

- On the basis of the results of the analysis of variance it was found that between the levels of fuel consumption in the transport of technical roundwood of broadleaves with a John Deere 1210E forwarder in different operating conditions expressed in L/m^3, there were statistically significant differences at the level of 95% confidence, and that the investigated conditions can be grouped into four groups with average consumption ranging from 0.74 to 1.4 L/m^3;
- Conditions in which the tractor assembly made up of a Same Laser 130 tractor and an Imako TP 12 trailer with a Loglift 61F hydraulic crane was investigated were not statistically different, and the average con-

sumption for different operating conditions ranged from 1.0 to 1.8 L/m^3;

- There were no statistically significant differences among the average levels of fuel consumption expressed in L/m^3 in different conditions when a tractor assembly made up of a Same Silver 105 tractor and an Imako TP 12 trailer with a Loglift 61F hydraulic crane was investigated, so that common work norms can be adopted by grouping all the data. Average fuel consumption was 1.06 L/m^3;
- Average fuel consumption per unit of production decreases with an increase in the average volume of tour in all conditions and for all the investigated equipment;
- In similar operating conditions, average fuel consumption significantly differs between the forwarder and tractor assemblies, while there were no statistically significant differences among the investigated tractor assemblies.

REFERENCES

Arvidsson P.A., Eriksson P., Eriksson I., Rönnqvist S.M., Westerlund A.,Igeklint P. (1999): Smarter route planning for forwarders benefits both profitability and the environment, Forestry Research Institute of Sweden, Results nr. 22, Uppsala, Sweden

Athanassiadis D. (2000): Energy consumption and exhaust emissions in mechanised timber harvesting operations in Sweden, Sci. Total Environ. 255(1-3): 137-145

Bajić V., Danilović M. (1999): Istraživanje zavisnosti vremena seče i izrade drvnih sortimenata od prečnika na prsnoj visini i starosti stabala u hrastovo grabovim sastojinama, Šumarstvo 3-4 , Beograd.

Grecs Z. (1986): Protok energije u gospodarskom gozdu, Materijal za ekskurziju 18th IUFRO WORLD CONGRESS, Ljubljana, str. 1–5.

Danilović M., Stojnić D., Karić S., Sučević M. (2014):Transport Of Technical Roundwood By Forwarder And Tractor Assembly From Poplar Plantations, Nova mehanizacija šumarstva,Volume 35:11-21.

Favreau J.,Gingras J.F. (1998): An analysis of harvesting costs in eastern Canada, Forest Engineering Research Institute of Canada, Special Report SR-129

Johansson A. (2001): Forestry Costs and Revenues 2000, A year of storms and floods, Forestry Research Institute of Sweden, Results nr. 4, Uppsala, Sweden

Nordfjell T, Athanassiadis D, Talbot B.(2003):Fuel consumption in forwarders, International Journal of Forest Engineering 14 (2):11-20

Rebula E.(1989): Potrošnja goriva pri izvlačenju drva s traktorima IMT 560 i IMT 567, Mehanizacija šumarstva, 14(7–8):151–156

Sundberg U., Svanqvist N. (1987): Fuel consumption as an indicator of the economics in mechanization, Scand. J. For. Res. 1: 389-398.