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FUEL AND LUBRICANTS CONSUMPTION IN THE PHASE OF HARVESTING AND PROCESSING WOOD IN PUBLIC ENTERPRISE FOREST OFFICES VAREŠ SECTION 37

Potrošnja goriva i maziva u fazi sječe i izrade drveta na području P. J. Šumarija Vareš, Odjel 37

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Abstract
Chainsaw is the main tool for work, considering the terrain and soil in our country, in the process of the harvesting, and there is a big chance it will be the main tool in the future too. The goal of the research is to determine fuel and lubricant consumption of the chainsaw Husqvarna 372 XP, during the harvesting and making forest wood assortments, on the area of the Public enterprise forest, Vareš, section 37.
During the research, 50 trees of the fir and spruce have been felled. Range of the diameter was from 8 to 76 cm, and the volume of the assortments was 86.16 m^3. Volumetric method is applied in the measurement of fuel and lubricants, with precise determination of how much fuel it was in the thanks.
Analysis showed that there is a strong correlation between consumption of the fuel and lubricant (L/m^3) in relation to the size of the breast height diameter.
Average fuel consumption in the process of logging and preparation was 0.104 L/m^3, while the average consumption of lubricant was 0.023 L/m^3.
It is necessary to continue to pay great attention to the rationalization of consumption on fuel and lubricants, as well as reducing their harmful effects on humans and environment (introduction and usage of biodegradable fuels and lubricants).

Key words: chainsaw, fuel consumption, lubricant consumption.

INTRODUCTION – *Uvod*

Forest, as compared with other ecosystems, is one of the system with best energy efficiency (long accumulation of potential energy related to the biomass). But also you can't ignore the fact that forest management also requires energy.

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Energy consumption is a very important segment of production in forestry, especially in the process of exploitation.

Exploitation of forests, which includes cutting and preparing, attracting and transportation, is characterized by applying a large number of mechanized means and technologys.

Research that have been made are devoted to the selection cutting system, and in accordance with this, assortment method of making and harvesting of timber in tree stump was applied.

Usage of assortment methods for cutting and preparation of spruce and fir affects the higher consumption of fuel and lubricants in comparison to other methods.
Energy consumption in forest exploitation is almost exclusively related to liquid petroleum fuels. In carrying out the work on the harvest and production of wood in our country, motor chainsaw is a major asset for the cutting and preparation of wood due to the terrain and stand conditions, and the type of cutting in our country.

Trends in the development and improvement of exploitation go toward finding new techniques and technologies in order to increase labor productivity and cost of labor, humanization of human labor and rationalization of fuel and lubricants. This has great financial and environmental benefits.

Fuel and lubricant consumption for machines in forestry is related to a number of risks of pollution of forest ecosystems (HORVAT I ŠUŠNJAR, 2003).

In many sectors of forestry, especially in forest exploitation are used precisely these fuels and lubricants, which requires special study. Possibility of using biodegradable fuels and lubricants are explored.
There are no more particular regulations for forestry in Bosnia and Herzegovina which solve the question of the usage of fuels and lubricants that are environmentally acceptable, and there is no obligation or recommendations (type and quality) what kind of the fuels and lubricants to use. There are a large number of factors influencing growth in fuel consumption in forestry.
Influential factors in fuel consumption when working with a chainsaw can be divided into four groups: external factors, factors of the machine, the factors of technology and organizational factors (JOVANOVIĆ, 1990). These factors will be partially studied by this research.

RESEARCH GOAL – *Cilj istraživanja*

The research goal was to determine the fuel consumption when working with a chainsaw Husqvarna 372 XP, in the process of felling, cutting and preparing of forest wood assortments.

Fuel and lubricants consumption was measured when working with chainsaw, depending on characteristics of the tree and the characteristics of assortments.

RESEARCH METHOD – *Metod istraživanja*

The research included in this paper belongs to the group of research and exploitation which required choice of study and choice of technological processes, with the harvest and preparation phase with the use of chainsaws.

Investigations were carried out in the area managed by the Forest Management Company of the Zenica-Doboj Canton Ltd. Zavidovići, P. J. Forestry Vareš, section 37. The study site reflects the technological processes and working conditions in the harvesting and processing on large forest areas of Bosnia and Herzegovina.

Data collection was performed using the necessary equipment for recording: recording lumber, glass cylinders, funnel, dragonfly, ribbon and diameters.

When measuring fuel and lubricant, volumetric method was applied for determining the precise content of the fuel and lubricant in chainsaws tanks.

Volume of the products is determined based on the length and the mean diameter at the middle length of assortment (Huber's formula). Tree volume is determined by the double-entry volume tables for fir and spruce.

Recordings were initiated after preparation, during the June 2009 Year.

Microsoft Office Excel it's used during the statistical analysis of the collected data and making appropriate diagrams with equations and their coefficients.

RESULTS - *Rezultati*

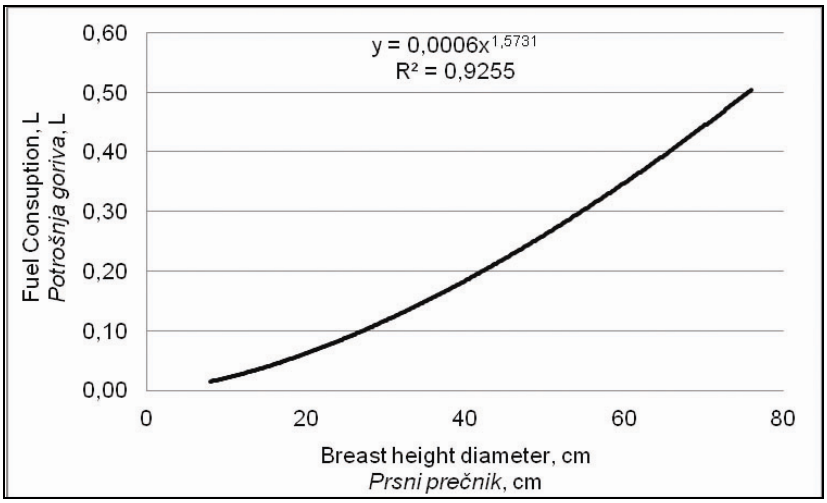
50 trees of fir and spruce are felled. Fir and spruce trees were of different heights and diameters, moderately grenades and uprights. Breast height diameter of the trees ranged from 8 to 76 cm, and the height of trees within the limits of 3.68 to 36.07 m, average diameter was 42 cm. Total volume of products is 86.16 m.

Dependence in fuel consumption compared to a felled and processed tree – *Zavisnost potrošnje goriva i maziva u odnosu na posječeno i izrađeno stablo*

An analysis of the dependence in fuel consumption compared to each felled and processed tree was made, based on collected data.

The most important factor for the determination of the fuel consumption is breast height diameter, and this consumption is expressed in L/tree and L/m^3.

Dependence of fuel consumption per tree in relation to the breast height diameter of the trees is presented in the graph 1.



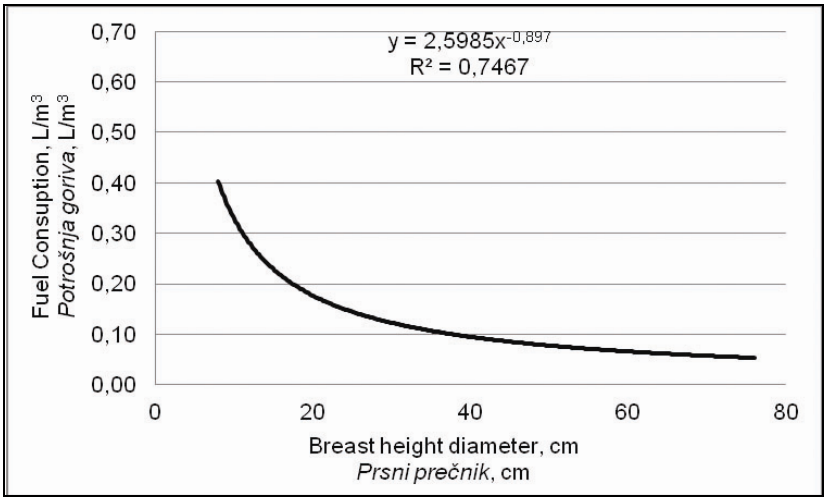
Graph 1. Dependence of fuel consumption per tree in relation to the breast high diameter

Grafik 1. Zavisnost potrošnje goriva od prsnog prečnika stabla

Analysis showed that there is a strong correlation (R^2=0.9255) between the fuel consumption and the size of the breast height diameter.

Research showed that for the trees with 8 cm diameter fuel consumption was 0.015 L, and for the trees with 76 cm diameter, this value was 0.545 L.

The analysis of the total felled trees showed that fuel consumption was 0.179 L per tree.



Graph 2. Fuel consumption (m^3/tree) and breast height diameter dependency

Grafik 2. Zavisnost potrošnje goriva po m^3 stabla od prsnog prečnika

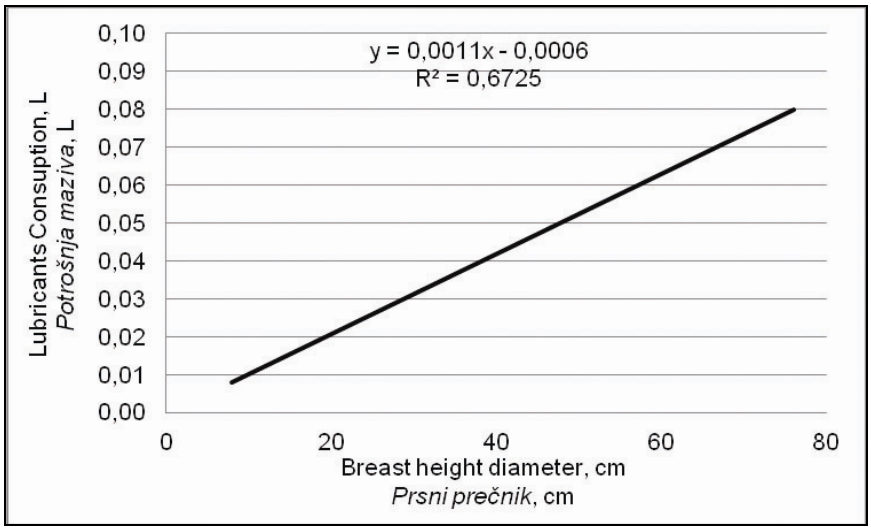
Regression analysis also showed that there are very strong correlations (R^2=0.7467) between the fuel consumption per unit volume and the size of the breast height diameter.

Therefore we can apply the rule: increasing the dimensions of the tree reduces the consumption of fuel and lubricants per unit or per m^3.

Fuel consumption per m^3 is less if tree is thicker, and vice versa, as can be seen from graph 2.

For breast height diameter 8 cm values were 0.400 L/m^3, and for breast height diameter 76 cm values were 0.053 L/m^3. The average fuel consumption per unit was 0.087 L/m^3.

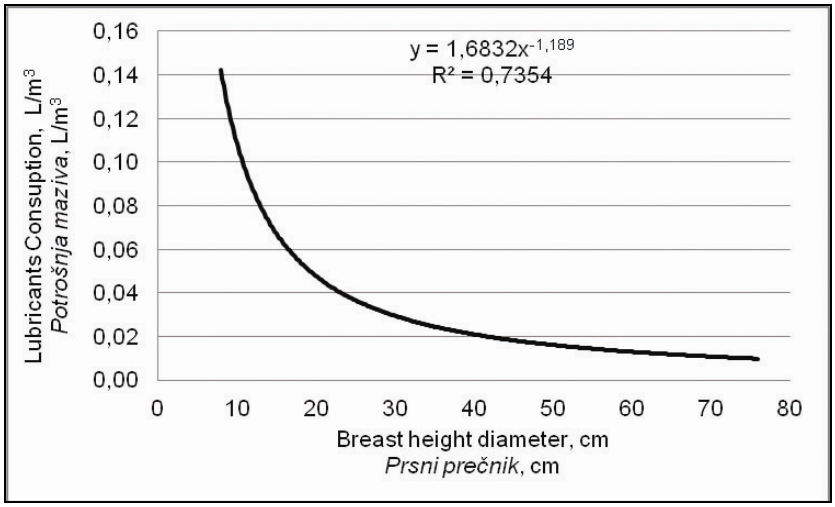
Using regression analysis it is determined correlation (R^2=0.6725) between fuel consumption and lubricants, as shown in graph 3.



Graph 3. Fuel consumption and breast height diameter dependency
Grafik 3. Zavisnost potrošnje maziva od prsnog prečnika stabla

After flattening values of the observed parameters, for the trees with 8 cm long breast height diameter lubricant consumption was 0.008 L. For the trees with 76 cm long breast height diameter lubricant consumption was 0.083 L, while the average consumption of lubricants per tree was 0.039 L.

Using defined regression analysis, it is found that there is also correlation (R^2=0.7354) between the lubricant consumption per unit volume of the tree and breast height diameter. Obtained values are presented on the graph 4, presented bellow.



Graph 4. Lubricant consumption per m^3 and breast height diameter dependency
Grafik 4. Zavisnost potrošnje maziva po m^3 stabla od prsnog prečnika

Lubricant consumption, just like fuel consumption per unit of the product (m^3) is less if the tree is thicker, and vice versa. Those flatten values were 0.142 L/m^3 for the trees with 8 cm diameter, and 0.009 L/m^3 for the trees with 76 cm. Average lubricant consumption per m^3 was 0.018 L/m^3.

Fuel and lubricant consumption and assortments dependency – *Zavisnost potrošnje goriva i maziva u odnosu na izrađene sortimente*

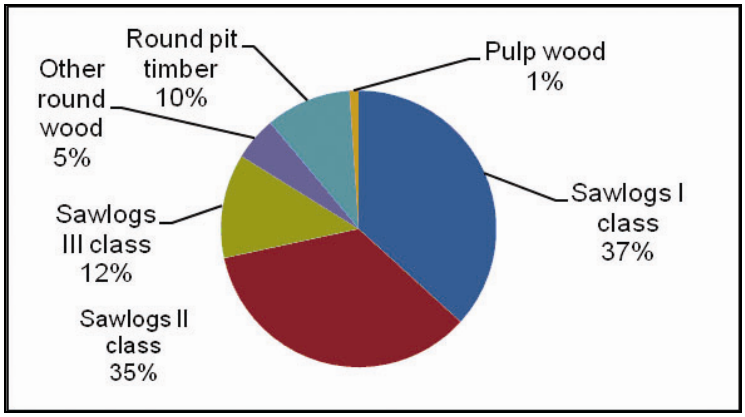
Fuel and lubricant consumption and assortments dependency was analyzed on the basis of the collected data.

Table 1 shows the maximum, minimum and average values of volume, and the average number of pieces of assortments.

Table 1. Characteristics of assortments
Tabela 1. Karakteristike izrađenih sortimenata

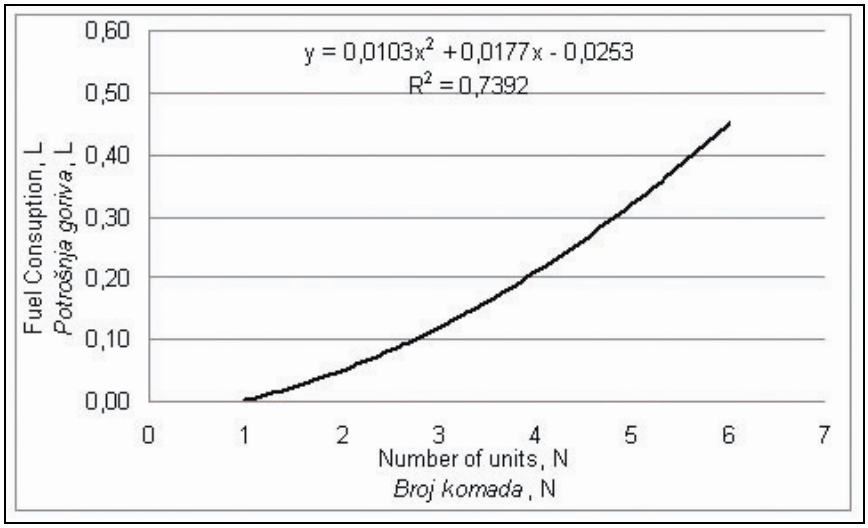
The average number of assortments (N)	Maximum volume pieces (m^3)	Minimum volume pieces (m^3)	Average volume pieces (m^3)
3.52	2.81	0.005	0.49

Graph 5 presents a structure of assortments from which we can see that the biggest participation has logs with highest quality class (37%), and lowest participation has pulpwood with 1%.



Graph 5. Structure of the assortments
Grafik 5. Struktura izrađenih sortimenata

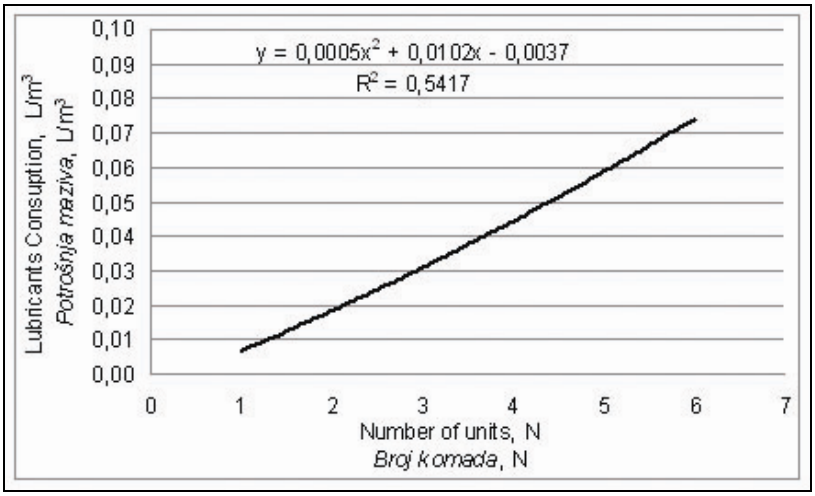
Graphs 6 and 7 presents fuel and lubricant consumption and number of the assortments dependency.



Graph 6. Fuel consumption and number of units dependency
Grafik 6. Zavisnost potrošnje goriva od broja komada izrađenih sortimenata

Regression analysis showed that there is correlation between fuel consumption (R^2=0.7392) and number of the assortments.

If the number of the assortments is bigger, fuel consumption is bigger too, what we can see on the graph 6. Those values were ranged from 0.051 L for making 2 pieces, to 0.452 L for making 6 pieces.



Graph 7. Lubricant consumption and number of units dependency
Grafik 7. Zavisnost potrošnje maziva od broja komada izrađenih sortimenata

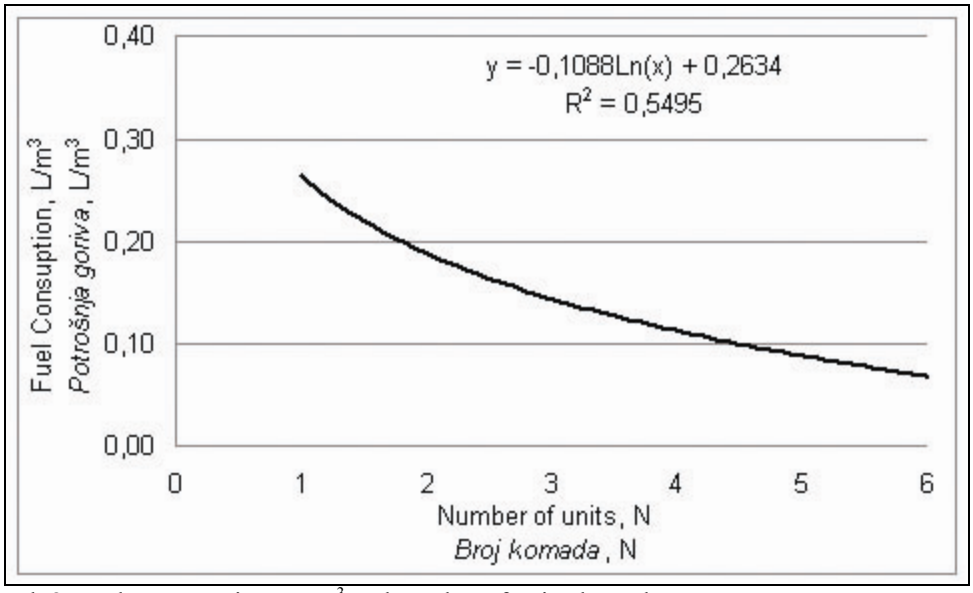
Consumption lubricant analysis also showed that there is statistical dependency (R^2=0.5417) between this parameter and number of the units.

On the graph 7 we can see that increasing number of units, consumption lubricant also increases.

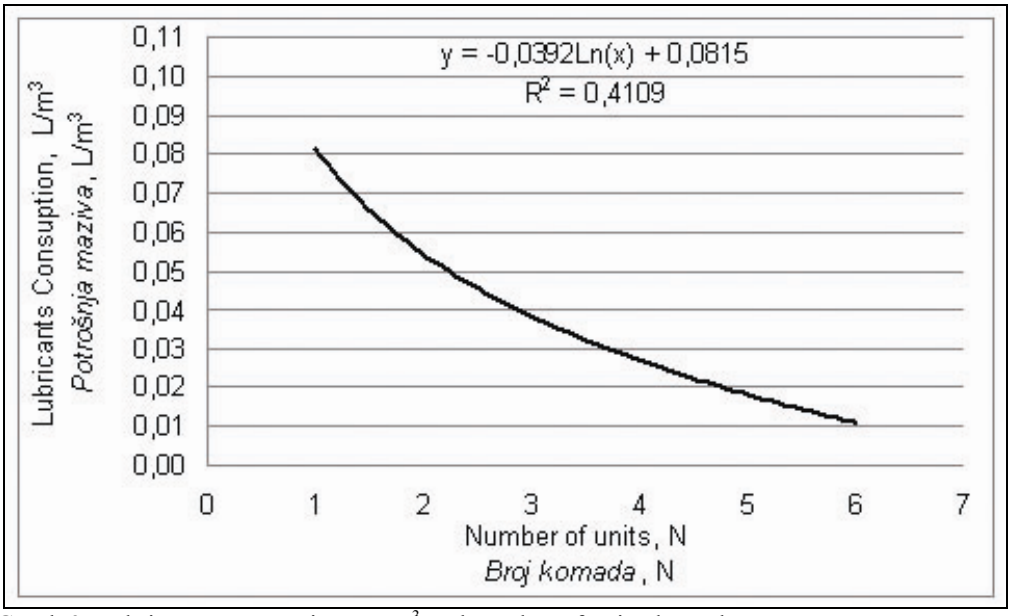
Those values for lubricant were from 0.019 L for making 2 units, to 0.075 L for making 6 units.

Dependency between fuel and lubricant consumption per m^3 and number of the wood assortments also was analyzed, and results are showed on the graphs 8 and 9.

Also, there is strong statistical correlation (R^2=0.5495) in lubricant consumption, respectively mean correlation (R^2=0.4109) lubricant consumption per m^3 of the wood assortments that were made.



Graph 8. Fuel consumption per m^3 and number of units dependency
Grafik 8. Zavisnost potrošnje goriva po m^3 od broja izrađenih sortimenata



Graph 9. Lubricant consumption per m^3 and number of units dependency
Grafik 9. Zavisnost potrošnje maziva po m^3 od broja izrađenih sortimenata

Analyzing the graphs 8 and 9, we can see that fuel and lubricant consumption per unit of the volume decreases with increasing number of the units. Those values for fuel are from 0.30 L/m^3 for making 1 piece, to 0.060 L/m^3 for making 6 pieces. For lubricant consumption those values were from 0.081 L/m^3 to 0.012 L/m^3.

Average fuel consumption per unit of the volume was 0.104 L/m^3, and lubricant consumption was 0.023 L/m^3.

Based on this data we can say that lubricant consumption is 22% of all consumption.

DISCUSION - *Diskusija*

In forestry, as a branch of economy, lubricant and fuel consumption has a special place. The most important parameters for assessment the consumption are: breast height diameter, volume of the tree, number of units, volume of assortments and volume of the average unit.

Reduction of fuel consumption could be achieved primarily with controlling the regular chainsaw safety, proper storage and distribution of energy, usage of appropriate equipment for fuel handling, as well as education and the stimulation of workers.

Fuel consumption was 0.104 L/m^3, and lubricant consumption was 0.023 L/m^3.

Analyzing the results of other authors can be seen that the consumption of fuel and lubricants, which is definitely different depending on a number of parameters (type of chainsaws, felling, wood types, etc.)

IGRIČIĆ (1983 A) came to the result that the average fuel consumption of motor chainsaws ranged from 0.30 to 0.44 L/m^3.

REBULA (1985 A) examined the fuel consumption of harvesting and preparation, and finds wide limits fuel chainsaws, which are in softwood ranging from 0.292 to 0.98 L/m^3, or at sawmills 0.129 to 0.244 L/m^3, while the lubricant is included with approximately 4% in fuel consumption.

SEVER et al. (1989) have examined the fuel consumption on works thinning stands was 0.163 to 0.296 L/m^3 and lubricants from 0.085 to 0.150 L/m^3.

Research by MARTINIĆ and VONDRA (1989) show that in Croatia the average fuel consumption for timber and processing ranges from 0.15 to 0.30 L/m^3 and lubricants 0.08 to 0.15 L/m^3.

BOJANIN et al. (1990) treated the problem of fuel and lubricants Stihl 056 chainsaw for felling and processing of oak, with the usage of assortment methods. Fuel consumption per m^3 of felled timber cordwood reported an average of all the trees and the thickness is 0.319 L/m^3 to 0.119 L/m^3 fuel and lubricants. The fuel consumption per m^3 of felled and processed wood production was 2.5 times higher, and lubricants are also 2.5 times more than felling and processing technical tree.

Harvesting and production chainsaw Stihl 064 (hardwood, stem-wood method) had a consumption per m^3 and the same amount of fuel L/m^3 0.062 and 0.03 L/m^3 lubricant (VONDRA I BOGOJEVIĆ, 1994).

Studies of machines with head measures fuel consumption 15-18 L/hour. (HEDEN, 1987).

BRANZ et al. (1983) suggest that technology with processors hires about 12 L/hour fuel propulsion.

Average fuel consumption chainsaw Husqvarna 372 XP in 2007 in the stage of harvesting and producing wood assortments in the FMUs Gornjebosansko"" L/m^3 was 0.15 and the average consumption of lubricant that is used to lubricate the bar and chain L/m^3 was 0.06 (GANIĆ, 2008).

Results showed that the consumption of oil in relation to the fuel is much smaller comparing to the results of other authors. Irregular working oil pumps can be one of the reason for this, which certainly can cause some malfunctions in the chainsaw. In accordance to this, chainsaw should bee serviced before using for research.

From all of the research we can see that there is a wide range of fuel and lubricants during felling and timber products production, which depends on a number of factors. The use of mineral fuels and lubricants has certain negative impacts on forest ecosystems and the living world.

Oil for chainsaw belongs to the group called total lost oil, and the problem is even greater because in our country there are no more particular regulations for forestry, which addressed the issue of the use of environmentally friendly fuels and lubricants which are labeled" friendly" environment.

For these reasons, it is necessary to continue to pay great attention to the rationalization of fuel and lubricants, as well as reducing their harmful effects on humans and the environment by introducing and using biodegradable fuels and lubricants.

CONCLUSIONS - *Zaključci*

- Research of consumption of fuel and lubricants chainsaw Husqvarna 372 XP are carried out in Public enterprise forest offices Vareš, section 37.
- In our sample, 50 trees of fir and spruce was felled. Breast height diameter of the trees ranged from 8 to 76 cm, and the total volume of assortments amounted to 86.16 m^3.
- The analysis shows that fuel consumption increases with increasing diameter.
- With increasing thickness of trees, fuel and lubricant consumption per m^3 of timber produced decreases.
- The average fuel consumption per tree was 0.179 L, with a correlation coefficient (R^2=0.9255), while the average consumption per m^3 tree was 0.087 L/m^3, with a correlation coefficient (R^2=0.7467).

- Average consumption of lubricants per tree was 0.039 L, and the value of the correlation coefficient was (R^2 = 0.6725), while the average consumption of lubricants per m^3 tree was 0.018 L/ m^3, with a correlation coefficient (R^2 = 0.7354).
- The average fuel consumption per m^3 assortments was 0.104 L/m^3, and the same lubricant consumption 0.023 L/m^3**.**

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Sažetak

U iskorišćavanju šuma, faza sječe i izrade, motorna lančana pila predstavlja glavno sredstvo rada s obzirom na terenske i sastojinske prilike u našoj zemlji, te način gospodarenja predviđa da će i u dogledno vrijeme ostati glavno sredstvo.

Cilj istraživanja je bio utvrditi potrošnju goriva i maziva motorne pile Husqvarna 372 XP prilikom sječe i izrade šumskih drvnih sortimenata na području P. J. Šumarija Vareš, Odjel 37.

U sklopu istraživanja ukupno je posječeno 50 stabala jele i smrče. Prsni prečnik stabala se kretao od 8 do 76 cm, a ukupna zapremina izrađenih sortimenata je iznosila 86,16 m^3.

Kod mjerenja potrošnje goriva i maziva primjenjen je volumetrijski metod sa preciznim određivanjem sadržaja goriva i maziva u rezervoarima motorne pile.
Provedenom analizom ustanovljeno je da postoji jaka korelaciona veza između potrošnje goriva i maziva (L/m^3) u odnosu na veličinu prsnog prečnika.

Prosječna potrošnja goriva po stablu iznosila je 0,179 L, sa koeficijentom korelacije (R^2=0,9255), dok je prosječna potrošnja po m^3 stabla iznosila 0,087 L/m³, sa koeficijentom korelacije (R^2=0,7467).

Prosječna potrošnja maziva po stablu je iznosila 0,039 L, a vrijednost koeficijenta korelacije je iznosio (R^2=0,6725), dok je prosječna potrošnja maziva po m^3 stabla iznosila 0,018 L/m³, sa koeficijentom korelacije (R^2=0,7354).

Iz analize svih parametara došlo se do podatka da je prosječna potrošnja goriva po jedinici zapremine izrađenih sortimenata iznosila 0,104 L/m^3, dok je potrošnja maziva po jedinici zapremine izrađenih sortimenata iznosila 0,023 L/m^3. Iz ovog podatka se može konstatovati da potrošnja maziva čini 22% od ukupne potrošnje goriva. Obzirom na dosadašnja istraživanja, potrošnja maziva je znatno manja u ovim istraživanjima, a kao razlog može se pretpostaviti da je u pitanju ne regularan rad uljne pumpe.

Potrošnja goriva i maziva prilikom sječe i izrade šumskih drvnih sortimenata zavisi od velikog broja faktora, a među najvažnije uticajne faktore spadaju veličina prsnog prečnika, zapremina stabla, broj komada izrađenih sortimenata, zapremina izrađenih sortimenata i zapremina srednjeg komada izrađene oblovine.

Uštede goriva i maziva bi se mogle ostvariti prije svega redovnom kontrolom ispravnosti motorne pile, pravilnim skladištenjem i distribucijom energenata, upotrebom adekvatnog pribora za manipulaciju gorivom, kao i obrazovanjem i stimulacijom radnika.

Potrebno je i dalje posvećivati veliku pažnju racionalizaciji potrošnje goriva i maziva, kao i smanjenju njihovih štetnih uticaja na čovjeka i okoliš (uvođenje i korištenje biorazgradivih goriva i maziva).