# ANALYSIS OF THE FIRST STEPS IN THE INTRODUCTION OF THE HARVESTER AND THE FORWARDER IN LOGGING, IN BULGARIA

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**ABSTRACT:** This paper reflects the studies conducted within a 2-year period, with some interruptions due to repairs, which have been made on the first and - by the moment, - the only machines as the harvester and the forwarder are, to be used for logging in Bulgaria. The above mentioned machines are: John Deere 1270D and John Deere 1110D, respectively, bought as second hand ones.
The plantations consist of white and black pine cultures. The productivity has varied from 28 up 51 m³/day an average diameter of 0,218-0.307 m³/tree, moreover, in bare thinning (after calamities but in a good state appropriate for a work by the afore indicated machines), and there has been found out a high correlation with the kind of cutting, the volume of the trees and of the cargoes, and the distance of haulage. The highest share of the total working hours has been considered of 57,8% of working hours followed by 18,0% of hours for maintenance and hours required for repair, i.e. 24,2% of the shift work.
The analysis of the observations shows as a result a comparatively low and a highly variable productivity, mainly due to the technical status of the machines and the low qualified operators. There is an enormous difference in productivity between operators working abroad and the ones in our country. An insufficient grade of professionalism and experience has been considered, especially when the harvester was used for works. It may be said: in fact, the only operators in Bulgaria are 1 for harvester operations and 2 for forwarder ones. The difference consists of the fact that the Bulgarian operator usually places the machine in a wrong position while working and operates with a low speed of the operating parts.
The world practice has proved that the companies aim at transferring to a fully machinized sortiment technology while in our country factors as a number of firms working in that sector, the low logging volume, the bad forest road network are reasons for which that progress is not the topic of the day, yet. Such a transition requires a new legislation and significant financial costs. The observations recorded in that study confirm that after removing the above mentioned failings that kind of the machines shall be a good investment leading to a high level of productivity. Notwithstanding the fact that man is unable to estimate the influence of all the existing factors because of and regards to their variety, the results obtained by the study can be used for a larger introduction of the harvesters and forwarders in the logging, in Bulgaria.
**Key words:** logging, new technology, harvester, forwarder, productivity, operators, activity analysis

## INTRODUCTION

When harvesters are used, the working time is 71% of the total shift time Glöde (1999). The greatest share is taken up by the working hours of 74.8%, followed by the hours for maintenance of 9, 2%, and the time required for repair: 5,9% of the shift time (Dvorak, 2010).
On the basis of the available data, according to Väätäinen et al. 2007, the average productivity of the single-grip harvesters at the stems average volume of 0,3 $m^3$ is of 18 $m^3$ PMH approximately, in clear cuttings. The productivity of the harvester depends upon many factors, as following ones: the forest stands composition, the forest area, character of the surface, the relief, the operator` s motivation and habits, the character of the tree crown, the planned works, the trees size, the number of the assortment species, the quantities of the trees in the cutting

area, the undergrowth density and the structural characteristics of the machines (Richardson, 1989; Makkonen, 1991; Jiroušek et al., 2002; Suchomel, Spinelli, Magagnotti, 2010).
When Timberjack 1270 harvester and Timberjack 1010 forwarder are used, the productivity obtained in assortment harvesting is of 16,9 $m^3$/PMH by Timberjack 1270 harvester and 14,3 $m^3$/ PMH by Timberjack 1010 forwarder, at the average stem volume of 0,32 $m^3$ (Gingras, 1994), while Gerasimov et al. (2012) with harvester John Deere 1270 D harvesting operations in forest stands composed of spruce (48% on average), pine (19%), birch (22%), and aspen (11%), with an average stem volume 0.31 m u.b. the cut-to-length harvesters produced are from 4.3 to 14.9 m u.b./productive machine hour (PMH) and 16.0-49.5 m u.b./stem processing machine hour (SMH). The operation of the tree processing (0,05-2,00 $m^3$/stem) varies from 62 to 171s (0,02-0,24 h/$m^3$).
According to Vadim et al. (2012), the distribution of the harvester work-cycle elements is, as following: 55% tree processing time, 16% trees felling time, 4% for the harvester moving in the plantation (site) and 27% for idle running while the forwarder work-cycle includes: 73% for loading time, 16% for wood transportation, 8% for movement of the unloaded machine and 3% for idle running.
At the moment, the manpower, i.e. the operators, which work performance depends upon training and experience, is being taking more and more for a key factor contributing to a high productivity achievement (Dvořák, 2010).
The productivity of the harvester is closely related to the stem volume and the forest stand composition (Richardson, 1989 ; Makkonen, 1991; Bulley, 1999; Gellerstedt et al., 1999). The time consumption for felling and processing with Valmet Snake is a function of the tree volume and the silvicultural treatment strategy. The locomotion time depends upon the number of trees felled per harvester stop, soil bearing capacity and terrain slope (Stampfer and Steinmüller, 2001).
The productivity of the forwarders is highly correlated to the payload volume and the average distance of the haulage, i.e. there is a raise in productivity when the payload increases and a drop in it at a greater average distance (Valenta and Neruda, 2004; Bergkvist, 2009; Zimbalatti, Proto, 2010).
Enormous differences exist among the operators and the levels of their training. Regardless of that, if there are good operators, good cares should be taken for them, as such operators can be considered the most precious assets (Purfürst, 2007).
It is a fact that the effect exerted by the harvester operator on the productivity of the entire system has been neglected for a long time (Purfürst, Erler, 2011). For that reason, 10-15% of the differences in the operator` s performance are due to the differences in machinery, 20-30% are explained by a more effective control exerted by the management bodies and 50-55 % result from a better planning and a prompt adoption of decisions. (Väätäinen et al., 2004).
Besides, it should be said that general factors, as, for example, the following ones: labor conditions, working time, as well as operators` motivation significantly differ in different States (Liden, 2005). And yet, the differences in achievement of a better productivity are still great, even among the so called " experienced " operators (Purfürst, 2010).
Preplanning and pre-execution shall be obligatorily provided. And, especially, the harvester drivers` skills are of a particular importance. It is a fact that good operators only feel sure in the cabin. Any ineffective and dangerous operation shall be avoided. The technical capabilities of the devices are really considered as risk factors for the good operator. From our viewpoint, many weeks are needed to find a proper a proper rhythm of work. Over 1000 hours of work are required, as a minimum, to get a command of that machine.

## MATERIAL AND METHODS

This paper reflects two-year studies with intervals necessary for the repair of the first harvester and forwarder machines, - and for the time being, the only ones in Bulgaria, - used in logging: John Deere 1270D and John Deere 1110D, respectively, both of them second hand purchased. (Fig. 1).
The study has been performed in Black pine cultures (Pinus nigra Arn.) and White pine ones (Pinus silvestris L.) located on relatively plain terrains. The development of the plantations has come to a standstill after fires and calamities, yet, these sites are suitable enough for operations performed by the above said machines under observation. The forestry objectives include release of such areas for new afforestation by clear cuttings.
Data collection has been separated in dependence of the machinery kind and each machine has been examined in its proper production environment. In addition, some independent variables have been also collected as related to the above said machines. These variables have included the trees diameter at breast height, the slope and the nature of the terrain. A photo of the working time has been taken by chronometrage and the measurement of the forwarding distance by a measuring tape.
The harvester cycle includes moving in the plantation, search tree, harvester head position, felling of the tree, delimbing and bucking stacking, depending upon the assortment species. The forwarding includes traveling empty, loading, in dependence of the assortment species, traveling full, unloading, sorting out of materials.


Fig. 1. John Deere 1270D harvester and John Deere 1110D forwarder in working process

It has been established in the course of the works that the operator should be familiar with forestry. But it is obvious that great differences exist in productivity among the different operators.
The skilled and experienced operator is a good observer on the entire system, being able to a prompt and reliable sensory-motor reaction.
The specific requirements of the survey are based on the comprehension that an effective operative management requires clear objectives, enough information and a realistic idea of what the process itself means. In this study, we represent the very situation, such as it is in Bulgaria, regard to the utilization of the contemporaneous multifunctional machines, of course, in comparison with their use in the world practice, as well as with the traditional technologies for forests use, mainly based on the process of forest exploitation, i.e. using motor chain saws, tractors provided with winches and cable lines. The economics of using the harvester technology

depends also upon the forwarder work. The loading factor of the forwarder is compared to that one of other machines when a forwarder is used in a combination with a harvester. In our case, while the forwarder is working, the harvester shall be expecting for ready material, because of the frequent repairs of the latter machine. It would be better, of course, to act expediently providing in advance that such material were available and then proceed to its forwarding. But it is a fact, in our country, these two machines only have been operating for a short period. That is why it was necessary to apply to works that same technology as appropriate.
The data collected in the course of the study have been subjected to a regression analysis with the purpose to develop regression models relating elemental time to some independent variables. The estimates of the total cycle time both for harvester and forwarder have been computed with the aim to get the range of sums of the independent variables.

## RESULTS AND DISCUSSION

Table 1 illustrates the results achieved by working with harvester John Deere 1270D and forwarder John Deere 1110D and the taxation indices of the plantations in the cutting area where the concrete studies have been performed.

Table 1. Characteristics of machinery expenditure and productivity

| Indices | John Deere 1270 D Harvester | John Deere 1110 D Forwarder |
|---|---|---|
| Machine made dating, year | 2006 | 2006 |
| State Forestry of Kotel – Section 89e; SFB composition – bpc 10; age – 55 y.; DBH – 34 cm; H – 19,0 m; complex valuation– 2; completeness– 0,7; storage– 432 $m^3$/ha; relief terrain – plain slope at the lower edge $22^0$ | | |
| 1. Cost estimate for 1 month: | | |
| Fixed costs | | |
| Cost of the machine, € | 175000 | 75000 |
| Insurance: €/year | 30000 | 18000 |
| Variable costs | | |
| Total time in days | 20 | 20 |
| Working hours | 130 | 130 |
| Fuel consumption, € | 915 | 550 |
| Motor oil consumption, € | 100 | 70 |
| Hydraulic oil consumption, € | 75 | 30 |
| Consumption of oil for chain, € | 50 | |
| Overhaul costs for the period, € | 160 | 80 |
| Expenses on salaries and wages, € | 550 | 550 |
| 2. Productivity of the machines | | |
| Average productivity, $m^3$/day | 51 | 44 |
| Forwarding distance, m | | 800 |
| Average load volume, $m^3$ | | 9,3 |
| Assortments: d cm - logs, at the thin end - 30(15%) и 18-29(40%), for beams - 16-18(10%) and for cellulose | | |

Note: With the purpose to achieve a greater efficiency in the steeper sectors which consisted 14% of the area, the whole-tree haulage was being performed using a TK 40 Bolgar skidder along with the harvester.

It can be seen that the average daily productivity of the harvester is 51 $m^3$ while that one of the forwarder 44 $m^3$, the time and the costs for the harvester repair excluded. What makes an impression is the scarce productivity of both of the machines. It is relatively low and highly variable: mainly due to machinery technical state and poorly qualified operators. The difference in productivity between the operators abroad and in our country is significant, due to our operators` insufficient professionalism and experience, especially with the harvester. That difference consists of a bad positioning of the machine by the Bulgarian operator in the course of works and of his operations performed at low speeds of its working organs.

The trees shape and size exert a direct effect on time for processing related to the effective time in machine hours, and, especially, with the increase of the stems average size. The productivity of the machines can be raised by increasing the time for stems processing instead of improving the methods of work, i.e. if, for example, it is possible to arrive at more than 0, 7, the productivity should raise over 100 $m^3$/day.

Table 2 shows the operating costs and time consumption during the work with the above said machines examined in this study. The observations show that while the harvester was used, the time, required for the processing of one tree which volume was of 0,218 – 0,307 $m^3$/tree, was varying from 115 to 182 sec. and decreasing by reducing the number of the obtained assortments: that is to say, by reducing the size of the trees. The highest share was noted of the bucking and the felling time, as well as of the time for the harvester moving in the cutting area, as of 50%, 13% and 13%, respectively. Using the forwarder, the time was varying from 80 to 117 min./cycle, and the highest share fell to the time of unloading, the times of transportation to and moving in the cutting area: of 33%, 12%, 28% and 13%, respectively (Fig. 2).

Table 2. Operating costs in a time consumption when one tree was processed by harvester John Deere 1270 D and one load was haulage by forwarder John Deere 1110 D

| № in order | John Deere 1270 D Harvester | | John Deere 1110 D Forwarder | |
|---|---|---|---|---|
| | Operation | Time - in sec. | Operation | Time - in min. |
| 1. | Moving in cutting area | 17-24 | Traveling empty | 8-12 |
| 2. | Search tree | 5-10 | Moving in cutting area for loading | 10-15 |
| 3. | Actuating harvester head | 5-10 | Stacking of the assortments in the cutting area | 12-17 |
| 4. | Cleaning under tree | 7-12 | Loading | 27-38 |
| 5. | Inclusion tree, advancing down, cutting tree | 16-24 | Traveling full | 12-16 |
| 6. | Summing up the tree to place splitters | 8-10 | Unloading | 11-13 |
| 7. | Advancing the 1st assortment, delimbing, bucking ets. (max. 4 assortments) | 57-92 | Stacking of the assortments in store | 0-6 |
| | Total: | 115-182 | | 80-117 |

It has been ascertained that no common rule exists for a statistically significant correlation of the single operating costs and time consumption. Such correlation was noted, to a certain extent, in

bucking operations when the trees diameter was taken into consideration, during the work with the harvester, and in transportation, depending upon the forwarding distance, when the forwarder was used, but its degree of significance was low. It is due to high variations in the precision of the operations performed by the operators and that is why it was impossible to find out other substantial relations in the examined processes. For the same reason, the observations shall go on also in the future, after that a sufficient experience shall be gained by the operators.

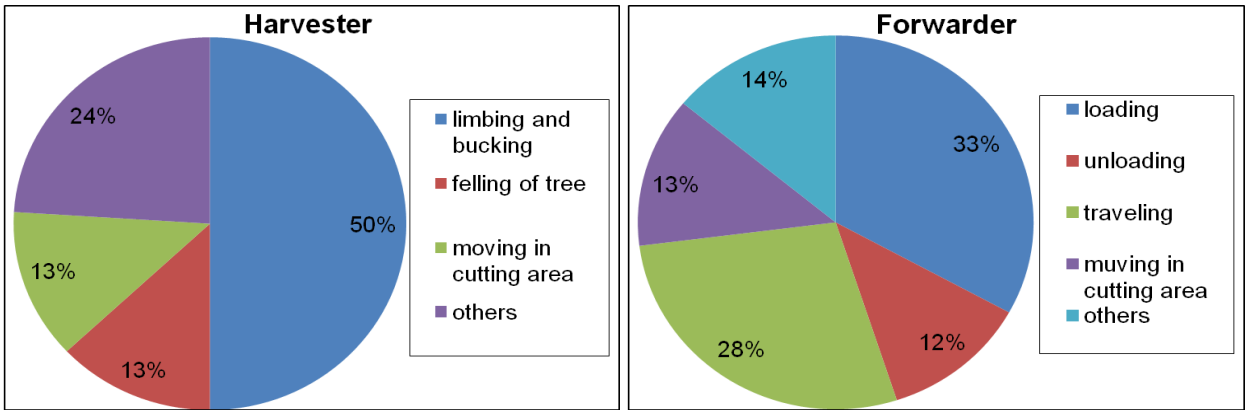

Fig.1. Distribution of time for machine work

The obtained results shall be used for an effective introduction of machines as the above indicated ones in Bulgaria, taking into account the concrete conditions for that. Any potential user of harvester and forwarder gets a possibility to make his own cost estimates in different conditions and to assess the competitiveness of alternative variants, especially, in such firms which have been still applying conventional technologies to haulage by tractors and where the cheap manpower is a hindrance to investments for specialized forest machines.
The technical state of the machines is of a great importance for the timely assimilation of wood, especially in cases of work in calamity stands (Table 3).

Table. 3. Repair operations performed on the Harvester and the Forwarder in 2013

| | More important repair operations | Cost |
|---|---|---|
| John Deere 1270 D Harvester | Replacement of the hydromotor, JD1270D HP computer, the brake disc and others | 35975 € |
| John Deere 1110 D Forwarder | Gaskets, valves, brake system and others | 2325 € |
| | Total: | 38300 € |

What shall be considered of a significant importance for the professionalism and the experience of the operators working with multi-operational machines is gaining of knowledge by specialized education. It is obvious that well trained forest machines operators are able to provide for a higher productivity: doubled and tripled, compared to that one given by the actually working operators which training courses are usually conducted directly within the enterprise or firm.
There are few differences in the direct operating costs of the various machinery systems. That is why many firms tend to transfer their activities thoroughly to mechanized technologies. In prospective, that offer an opportunity to a reduction of operating costs, to a raise in productivity, and subsequently, to an improvement of the firms or enterprises financial state.

Taking into account the costs and time consumption in other countries where it has always become a tradition to use harvesters and forwarders, it is interesting to make some comparisons. For example, in other countries, the time for moving of the harvester consists of 3-6% while it is over 13% in Bulgaria. In the above mentioned countries, the idle time due to reasons of technical, technological and other character is up to 15% while in our one, the time for repair and maintenance of the harvester only is of 42% of the working hours (comprised the idle time for repair in 2013, distributed within the examined period). The operating time consists of 53% of the total working one. A little better are the results about te forwarder where that time consist of 65% approximately. As for the machine utilization extent, the results show 61% for the harvester and 74% for the forwarder, in Bulgaria, while in the other significantly experienced states the indices are over 85%. It depends, to the highest extent, upon the machinery state and the operators` professionalism. The full costs, the overall expenses for the repair of the machines, the harvester and the forwarded comprised, are of 7 €/$m^3$ (64 €/hour) and 6 €/$m^3$ (44 €/hour), respectively. As a whole, the indices in our country are worse, compared to those ones indicated in the papers (Mäkelä, 1986; Kärhä et al., 2006; Väätäinen et al., 2007; Väätäinen et al., 2008; Bergkvist, 2009 et al.). The main reasons for such results are the machines state and the poorly qualified operators, particularly, the harvester ones.
The process of assessment of the impact on the environment in the forest proves that any machine, to a different extent, damages the soil, especially when the operations are performed on sand and moisture soils. Such damages occur to a greater extent when the forwarder is used and to a lower when operations are done by harvester; however, the use the above mentioned machines causes less damages than works by tractors and trucks which are being actually used in our country. Higher is the impact by the harvester on the undergrowth and the subforest. In that case, there is also an impact by the subjective factor. The ergonomic parameters permit to determine that the best working conditions, in respect to ergonomy and safety, have been created when mechanized cutting by multi-operational machines is used.

## CONCLUSIONS

The productivity of harvester John Deere 1270 D is 51 $m^3$/day and of forwarder John Deere 1110 D - 44 $m^3$/day. It is comparatively low and highly variable, mainly due to the technical state of the machines and poorly qualified operators. A raise in productivity is achieved by increasing the size of the trees, at a maximum loading and by improving the operators` work.
The highest share of the total working hours is that of the operational time followed by the time for maintenance: 18,0% and for repair: 24,2% of the shift time. The distribution of the harvester working cycle by elements is as following: 50% - time for trees processing, 13% - for trees felling, 13% - for moving in the stand and 24% - for the remaining time, while the distribution of the forwarder working cycle is: 33% for the time of loading, 12% - for unloading, 28% - for traveling, 13% - for moving in the cutting area and 14% - for the remaining time.
There are many cases when the operator prefer to access by the harvester nearer to the trees instead of having recourse to the maximum range of the manipulator. That way of operating leads to a loss in productivity, due to the frequent moving of the machine. It also reflects on the forwarder.
In problematic plantations, such as calamity ones, the inexperienced operators lose much time to arrive at a right decision for trees processing, especially in the beginning and at the end of the work. The multistage, reiterative and frequent use of the equipment for the same operation is considered a very disadvantage.
Usually, for the effective functioning of the system, a reserve of 3-5 days for wood supply between the two phases shall be taken into account when the harvester is used for work: More time is not necessary because probable risks may occur and cause major operational delays.

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