Utilization of Forest Residue in Poplar Plantations

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Abstract:
This article deals with issues concerning forest residue utilization from poplar plantations in Vojvodina. Following the harvest of wood assortments in poplar plantations a significant quantity of wood needs to be removed in order to start a new production cycle. This quantity is a potential raw material for energy use, but the costs of utilization are high and often exceed its value. In the regions where it is possible, with a certain fee, the local population is allowed to utilize the residue for their own needs, but in most areas there is no interest among the population for this raw material due to its remoteness, which then requires engagement of workforce for jobs of residue removal.

Taking into account the current trends in energy markets and the requirements that arise from the prescribed national obligations concerning the share of renewable energy sources and the problems arising in the production process, the research of the most suitable technology for utilization of the residue from poplar plantations has been conducted.

The research was conducted on the territory of the "Sremska Mitrovica" forest holding in the plantation of Populus×euramericana 'I-214' which was harvested by a John Deere 1470 D ECO III harvester.

The goal of this research was to select the most suitable technological process on the basis of the production effects. Total wood mass that remained in the harvest site after harvesting, in the first case, was transported with a forwarder and a tractor assembly to the temporary landing that lies on a truck road. The chipping of the residue was conducted on the landing by a chipper mounted on the truck.

In the second case, pulpwood was processed by the Stihl 026 chainsaw using the 1MR organizational form of work, following the harvest. After that, the wood was transported by a tractor with a trailer to the temporary landing. Wood residue following the processing of pulpwood was chipped by a LIPA-AHWI 600 mulcher mounted on a SAME IRON 210 DCR tractor.

The selection of the most suitable technological process was conducted by taking into consideration the analyses of various technical, economic, ecological and energetic aspects of utilization.

Keywords: poplar plantations, harvester, forwarder, forest residue, chipping, chainsaw, pulpwood.

1 Introduction

Most of the forest area in Vojvodina is managed by the "Vojvodinašume" PE. The annual net harvestable volume of wood is about 480,000 m^3. The percentage of branches, bark, stumps and shrubs, etc. in the total wood volume amounts to 40%, which is a considerable amount that can be used for energy production or other purposes (Fig. 1).

The forest residue that should be removed before the establishment of a new production cycle remains in poplar plantations after clearcutting (Fig. 1).

This forest residue, where possible, is used by the local people upon payment of a certain fee, or in some cases even free of charge, on condition that they remove the residue and enable the initial steps leading to the establishment of a new production process.

Figure 1: Forest residue in poplar plantations

In areas where there is no interest of the local people in the utilization of the forest residue, manpower and machinery have to be engaged for its collection and removal, which requires the expenditure of certain funds. Since this residue contains the slash of small dimensions scattered around the entire harvest site, the production costs often exceed the value of the produced raw materials.

Today, the share of forest residue in the energy sources of Serbia is minimal. The wood raw material in the existing energy and plywood production facilities is primarily class I or class II cordwood. The price of this raw material in the markets of Serbia and neighboring countries is high, and as such constitutes a large share of the total production costs, which thwarts the possibility of creating high profits to the user companies.

The price of this raw material is affected by production costs. These costs are high, primarily due to the so-called "rule of piece mass", which restricts the possibility of reducing the price of this raw material.

The operating conditions of forest utilization in lowland and hilly-mountainous areas are different. There are more opportunities for the application of modern machinery (multifunction machines) in lowland areas, even though they are characterized by frequent flooding and high groundwater levels (Bajić et al. 2005).

Until 2008, the felling and cross-cutting of wood assortments in Serbian poplar plantations mature enough for harvesting were performed using the chainsaw in the 1M+1R organizational form of work. Since 2008, the John Deere 1470 D ECO III multifunctional harvester has been in use in the poplar plantations mature enough for harvesting, in addition to the chainsaw, which is still the most commonly used device in the phases of felling and cross-cutting of assortments (Fig. 2).

The harvester outputs achieved in the poplar plantations mature enough for harvesting, range from 30.3 to 34.7 $m^3 \cdot h^{-1}$, depending on the method of work of the harvester used (Danilović et al. 2011).

The operating conditions in lowland areas are unfavorable during phase I of technical roundwood transportation, primarily due to the low carrying capacity of the terrain which is often subject to river flooding and the impact of groundwater (Jezdić et al. 1995).

Under these operating conditions forwarders and tractor assemblies are indispensable instruments of work. In difficult terrains and at shorter distances, forwarders have an advantage over tractor assemblies (Nikolić and Đoković 1986). The outputs of this machinery depend on many factors (type of transport vehicle, terrain characteristics, driver's skills, etc.), including the mean transport distance and the average volume of a piece, as factors with the highest impact on these outputs (Jezdić et al. 1995, Poršinsky 2000, Stankić et al. 2012).

After felling, cross-cutting and phase I of assortment transportation, a certain amount of wood mass intended for the production of short pulpwood and energy wood remains in the harvest site (Fig. 1).

The transportation of short pulpwood from the harvest site is performed using tractors with trailers, after which a part of the wood mass used for energy remains in the site (stumps, slash, branches, pieces of forked branches, strippings, etc.).

This forest residue should be removed from the areas for afforestation, thus enabling the initiation of a new cycle of wood production. The removal of this wood material from the area for afforestation is carried out in various ways, mostly by collecting and piling of branches and other slash, followed by burning in appropriate weather conditions or chipping with a mulcher. In the areas without nearby settlements, the utilization of forest residue by the local population is significantly lower, due to high transportation costs. Therefore, the engagement of manpower is necessary in these areas.

The utilization of forest residue in this way is not always the best solution, since a part of the energy generated by burning the forest residue is wasted.

In the operating conditions of short pulpwood production, some thin slash remains in the site. This slash should be collected in order to improve the efficiency of the hydraulic arm of the chipper, i.e. to enable a cost-effective use of the chipper. In addition, the effect would be greater if the stumps were extracted. In this way, the concentration of wood mass per unit area would increase, thus creating conditions for a reduction in the chipping costs.

The cross-cutting of long cellulose wood and cordwood in the poplar plantations mature enough for harvest in Serbia has become common. This has significantly increased the workers' output.

Under such operating conditions, the use of a harvester is cost-effective only in the case of very high harvester outputs (Danilović et al. 2011).

In 2009, started the ongoing research on the effectiveness of the harvester in the operations of felling and cross-cutting in poplar plantations. Among other things, this research should reveal the cost-effectiveness of the harvester in relation to stem properties. After felling and cross-cutting of the wood into assortments using a harvester, a part of wood mass that is subject to further processing remained in the site. The wood mass that remained after the work of a harvester was transported in a compact form to the temporary roadside landing by a forwarder. The chipping with a truck-mounted Heiz hack HM 14 800K chipper was performed at the temporary landing.

The aim of this study is the choice of a better technology option on the basis of the assessment of the effects of production.

2 Materials and methods

The study was performed in the territories of the "Sremska Mitrovica" Forest Holding (FH) and the"Novi Sad"FH. The cross-cutting of the pulpwood in the 1MR organizational work form, using the 2.6 kW power "STIHL" 026 AV chainsaw, was recorded following the work of the John Deere 1470 D ECO III harvester.

The recording of the pulpwood cross-cutting (Fig. 4), as well as phase I of the transportation of short cordwood (Fig. 5) and chipping of the forest residue (Fig. 6) were performed in the "Kupinski Kut" FMU.

The second technology option involved recording of phase I of the transportation of compact wood mass that remained after the felling and cross-cutting of assortments using a harvester (Fig. 9), as well as chipping at the temporary landing (Fig. 10).

Figure 2: Felling and cross-cutting using a harvester

Figure 3: Phase I of transportation using a forwarder

Figure 4: Cross-cutting of corwood

Figure 5: Phase I of transportation of corwood

Figure 6: Mulching

In these studies, photo chronometry was used as the recording method and the duration of the operations was measured by the flow method.

Within the projected technological schemes, the production of cordwood involved several operations, including the processing of cordwood, the cross-cutting of cordwood, splitting, shifting, the cross-cutting of struts and stacking. The transportation of cordwood was performed using an IMT 577 tractor with a single-axle trailer. The loading was performed by two workers. After transportation of the cordwood, the remaining wood mass was chipped using a LIPA-AHWI 600 mulcher mounted on a SAME IRON 210 DCR tractor.

The transportation of the long cellulose wood and branches was recorded in compartment 2 of the "Kupinski Kut" FMU. The transportation of wood to the temporary landing was performed using a

Timberjack 1210 B forwarder. The chipping was performed by the Heiz hack HM 14 800 K chipper at the temporary forest landing.

Figure 7: Phase I of wood mass transportation

Figure 8: Chipping at the landing

Figure 9: Collecting of forest residue

The number of recordings performed for the purposes of these studies meets the research requirements. The data analysis was performed using common mathematical and statistical methods.

3 Results and discussion

The output of the harvester achieved under these operating conditions amounts to 34.7 $m^{-3} \cdot day^{-1}$. Accordingly, the unit labor cost of using the John Deere 1470 D ECO III harvester is 3.5 $EUR \cdot m^{-3}$ (Danilović et al. 2011).

The effects of the Timberjack 1210 B forwarder, after a clear cutting with a harvester, were determined on the basis of recordings of 70 transportation cycles performed during 10 effective working days.

The logs were transported across the harvest site, by skid trail and finally by hard truck road. The calculated transport distance (the harvest site) under the studied conditions was 547.5 m.

The output achieved by the forwarder under these conditions is 93.2 $m^3 \cdot day^{-1}$. The calculated unit labor cost of using the Timberjack 1210 B forwarder was 3.06 $EUR \cdot m^{-3}$. The output of the forwarder is higher than the output achieved in the transportation of the roundwood of soft broadleaves from a site harvested using a chainsaw. This can be explained for by the longer time of loading and unloading of assortments, as well as longer movement time. The greater effect is the result of assortment grouping during the cross-cutting of assortments, i.e. reduced intersection of assortments while falling to the ground. These results are of particular importance in the assessment of the effectiveness of the harvester in the operations of felling and cross-cutting of assortments.

The recording of pulpwood cross-cutting was performed during 11 effective working days in winter conditions.

During the recording, a total of 106 stacks of cordwood were produced, i.e. the quantity of 103.5 m^3. The average time of transition from stack to stack was 0.67 $min \cdot m^{-3}$, and the average time of pruning and cross-cutting amounted to 20.4 $min \cdot m^{-3}$. The time of preparation for splitting, splitting, shifting, strut production and stacking was 24.1 $min \cdot m^{-3}$. Downtime (breakfast, chain sharpening, fuel filling, physiological needs, rest) amounted to 13.2 $min \cdot m^{-3}$.

The average output achieved in cordwood production was 5.36 $m^{-3} \cdot day^{-1}$.

The unit labor cost calculated on the basis of direct labour costs and outputs achieved in the cross-cutting of short cordwood amounted to 6.32 $EUR \cdot m^{-3}$.

During the transportation of the technical roundwood using forwarders, the branches were partially suppressed into the ground (trampled on) in some places, which made the cross-cutting of cordwood difficult, resulting in the more frequent sharpening of the chainsaw chain that in turn increased the share of downtime.

Phase I of cordwood transportation was performed using an IMT 577 tractor with a single-axle trailer. The loading and unloading of assortments was performed manually by two workers. The stacking of the wood at the temporary landing was performed to a height of 1 m.

The average output achieved in phase I of the transportation of cordwood was 17.91 $m^3 \cdot day^{-1}$. The unit labor cost of using the IMT 577 tractor with a single-axle trailer amounted to 5.89 $EUR \cdot m^{-3}$.

The forest residue that remains in the site after the transportation of cordwood should be removed before the initiation of a new process of production. The removal of this forest residue involves its collection and piling by hand, followed by burning or chipping. The chipping of the forest residue in these studies was performed using a LIPA-AHWI 600 mulcher mounted on a SAME IRON 210 DCR tractor. This way of working is a result of the unregulated conditions in the market of forest biomass in Serbia.

The introduction of modern machinery into the phase of terrain preparation for afforestation has been a significant progress in many respects, especially in the field of work humanization In this way, the problem of surface preparation for the establishment of intensive plantations has been solved to some extent (Danilović et al. 2009).

The retention of the chipped forest residue on the surfaces for regeneration can be justified only in terms of enriching the soil with nutrients for higher biomass production.

The recording of the operation of a LIPA-600 AHWI device aggregated with a Same Iron 210 DCR tractor in the aim of site preparation for afforestation after a clear cut was performed in March and April of 2011.

The recorded parameters within the projected technological scheme included the time of chipping, the time of turning and the time of justified and unjustified delays. The weather conditions during the recording were favorable.

The share of the mulcher operating time in the total time spent on mulching was 84.6%, and the share of downtime in the total time amounted to15.6%.

The share of the mulcher operating time on the same surface, i.e. the share of mulching in another passage, amounted to 14%. The average speed of the tractor during mulching was 6.69 $m \cdot min^{-1}$.

Under these conditions, the effect of the Same Iron 210 DCR tractor with the Lipa–Ahwi 600 mulcher is not related to the number of passes, but to the amount and structure of the material chipped. The mulcher output amounted to 0.56 $ha \cdot day^{-1}$ and the fuel consumption was 20.6 $L \cdot h^{-1}$. The unit labor costs amounted to 130.5 $EUR \cdot ha^{-1}$.

The second technology option included the felling and cross-cutting of assortments using the John Deere 1470 D ECO III harvester, followed by Phase I of technical roundwood transportation using the Timberjack 1210 B forwarder.

The compact residual wood mass that remained after felling was transported using the Timberjack 1210 B forwarder. During felling, a minor part of wood mass separated from the crown due to the impact force. However, it is a minor quantity of wood mass that may be significant for the enrichment of the soil with nutrients.

The unit labor cost was calculated on the basis of the direct labour cost of using the Timberjack 1210 B forwarder, and the output of 51.6 $m^3 \cdot day^{-1}$ achieved during mulching. This unit labour cost amounted to 5.54 EUR·m-^{3}.

The chipping of the wood material was carried out using a mobile truck-mounted Heiz o hack HM 14 800K chipper.

The unit labor costs of using the mobile truck-mounted Heiz o hack HM 14 800K chipper amounted to 2.62 $EUR \cdot m^{-3}$.

The comparison of unit costs of the two different technology options revealed lower unit costs for the second technology option, weighed against the first technology option.

4 Conclusions

⇒ The utilization of the forest residue from the plantations of soft broadleaves in Serbia is not in accordance with the society’s potential and needs.

⇒ The market of forest biomass in Serbia is underdeveloped, which has an adverse effect on the utilization of wood as an energy raw material.

⇒ The application of modern machinery in the technological process of forest utilization lowers the participation of physical labour in the cross-cutting of wood assortments.

⇒ The choice of technique and technology in the operations of forest biomass utilization for energy production should be made by analysing the various aspects of work.

⇒ The effects of the forwarder in phase I of assortment transportation are greater in sites where felling was performed using a harvester, than following felling with the chainsaw.

⇒ The 1MR organizational form of work used in the cross-cutting of pulpwood in plantations of soft broadleaves is an efficient solution, i.e. its effects are much higher, weighed against the1M + 1R organizational form of work.

⇒ The chipping of the forest residue using a mulcher, following pulpwood transportation, is of high importance in terms of preserving the nutritional potential of the soils.

⇒ The production of the compact forest residue at the temporary landing should be considered through the assessment of the employment of different means in felling, cross-cutting of wood assortments and phase I of transportation.

⇒ The unit costs of the technology option involving the cross-cutting of cordwood are higher than the ones of the technology option that involves chipping of the wood at the temporary landing.

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