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Universal tractor processor for working in forests of different ages

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Abstract. In this article, a universal tractor processor (UTP) is proposed. The UTP allows you to harvest all types of trees and process them into assortments and for fuel chips. The maximum productivity of the UTP for the output of assortments will be in the case of logging business trees with the production of chips (option 2). The total productivity of the UTP will be maximum when it is working by the option 3, when business and low quality non-commercial trees are harvested. In practice, if the goal is to maximize the output of business assortments, then the UTP work should be organized according to the option 1 or 2. If the time to clean up the logging residuals before the UTP is longer than the time to process the residuals into fuel chips, then option 2 will show the best results. In this case, in addition to the maximum output of assortments, additional products will be obtained – fuel chips. The maximum productivity of the UTP for the output of assortments is achieved if you exclude the harvesting of thin-sized trees (option 3).

1. Introduction

Different machines are used in logging operations today. For example, tractor processors (figure 1) [1]. Such tractor processors include a crane with cutting head for felling trees and a delimbing-bucking unit. The processor is usually driven by a general-purpose tractor.

The advantages of the tractor processors compared to harvesters are their relatively low price and low requirements for operator qualification, which makes them particularly attractive for low-volume logging.

The disadvantage of the tractor processor is that it does not process logging residues (LR), but leaves them in the cutting area. Meanwhile, the share of LR are up to 15-20% of the total volume of wood [2].

In order to use LR for example, for the production of biofuels, improved designs of forest machines have been developed and patented. For example, bundling machines [3-5].

These forest machines can be effective in solving some logging problems. For example, the problem of processing LR or harvesting thin trees. The use of such tractor processors in forests of different ages, where trees of different breeds grow, may not be very effective.

Figure 1. Tractor processor HYPRO755 with felling head [1].

The structure of trees by the volume of wood and the number of trees in pieces in different age forests of Russia is estimated as follows [5-7]:

- Low quality non-commercial trees (LT) make up about 30% of the total volume, and the number of trees in the cutting area is about 20 %.
- Thin trees (TT) with a diameter of less than 14 cm at a height of 1.3 m make up about 20 %, and the number of trees is 40...50 %.
- Ripe business trees (BT) make up about 50 %, and the number of trees is about 30...40 % of the total number of trees in the cutting area.

As you can see, in forests of different ages of Russia business trees that are suitable for processing into assortments are only 50 % by volume, or 30-40 % of the total number of trees. The rest of the wood is almost unused.

LT and TT, as well as *LR* can be used as biofuels. For example, as fuel chips [8-16].

It follows that for harvesting and processing all biomass of the forest stand in different-age forests, a universal forest machine can be in demand that can effectively harvest BT for assortments, and process LT and TT, as well as LR, for fuel chips.

2. Methods and Materials

This article discusses the universal tractor processor (UTP) developed by us [17], which allows us not only to produce business assortments, but also to carry out harvesting and processing LR, LT and TT into fuel chips.

The UTP conceptual model is shown in figure 2.

The UTP (figure 2) has a delimbing-bucking unit 1 for producing assortments from *BT*.

To cut trees, UTP is equipped with an accumulating cutting head 3, which is connected to the manipulator 2.

The UTP has a reception table for LT, TT, and LR with a movable base 4 and with enclosing walls 5. The table is placed on guides 6, along which it can move. The UTP is equipped with a chipping machine 7 for processing LT, TT and logging residuals into fuel chips, a pneumatic line 8 for feeding chips from the chipping machine 7 and a trailer-hopper 9 for chips from the pneumatic line 8. In transport position, the table with the guide takes a vertical position.

Before starting work, the UTP is located within the working zone in the cutting area. In this case, the table with guides takes a horizontal position.

The UTP cuts BT (figure 3 (a)) using the cutting accumulator head 3 one by one. Being cut off, with the manipulator 2 the BT is placed on the delimbing-bucking unit 1. The delimbing-bucking unit 1 clears the *BT* from branches and divides the trunk into assortments. The LR is transferred to the receiving table with a movable base 4. After crosscutting, the BT places on the delimbing-bucking unit 1, the LR accumulates on the table with the enclosing walls 5. After that, the table with the *LR* is moved along the guides 6 to the working window of the chipping machine 7 (figure 3 (b)). Then, with the movable base 4 of the table, the LR is sent to the window of the chipping machine 7 and crushed into fuel chips. The fuel chips are sent through the pneumatic line 8 to the trailer-hopper 9.

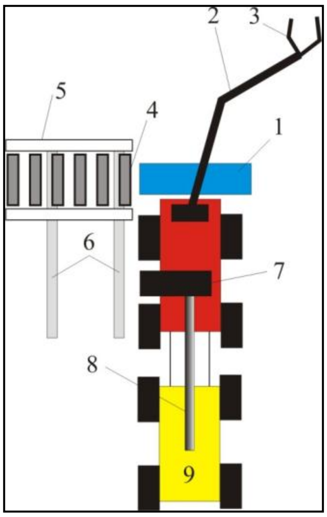

Figure 2. Conceptual model of the UTP.

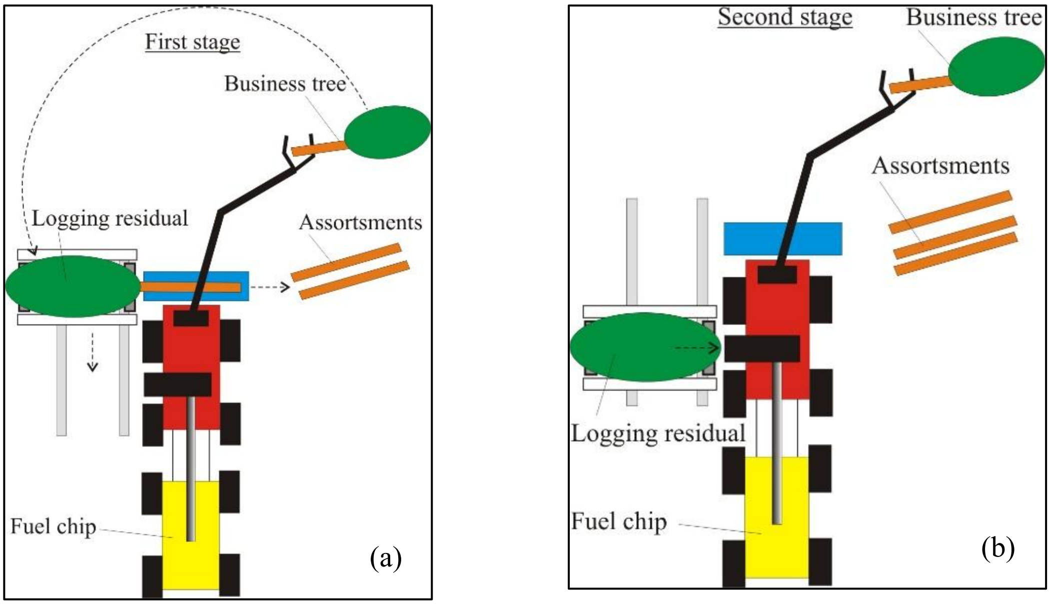

Figure 3. The UTP working with the BT.

When the UTP is working with the LT, the receiving table is first moved to the working window of the chipping machine 7 (figure 4). The LT are cut by the accumulating head 3 one by one. Then, with the manipulator 2 LT is placed on the movable base 4 of the receiving table. After that, with the movable base 4 of the table, the LT is sent to the window of the chipping machine 7 and crushed into fuel chips. The fuel chips are sent through the pneumatic line 8 to the trailer-hopper 9.

When the UTP is working with the TT, the receiving table is also previously moved to the working window of the chipping machine 7 (figure 5). The TT is cut off by the accumulating head 3, accumulating trees in the head to the maximum possible volume. Then, TT accumulated in the head are placed on the movable base 4 of the receiving table with the manipulator 2. After that, with the movable base 4 of the table, all TT are sent to the window of the chipping machine 7 and crushed them into fuel chips. The wood chips are sent through the pneumatic line 8 to the trailer-hopper 9.

Thus, the UTP considered in the article makes it possible to produce fuel chips from LR, LT and TT in addition to the assortments from BT.

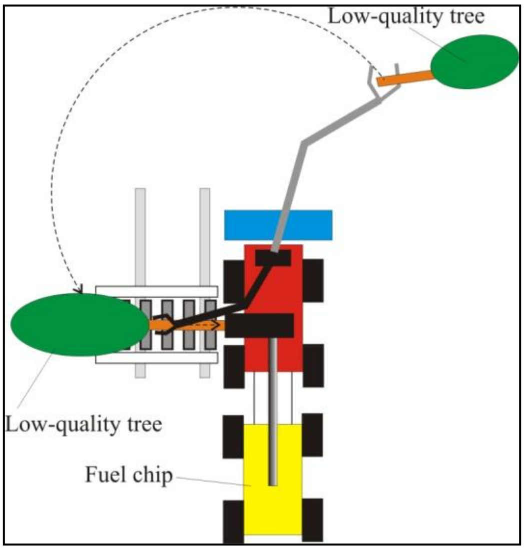

Figure 4. The UTP working with the LT.

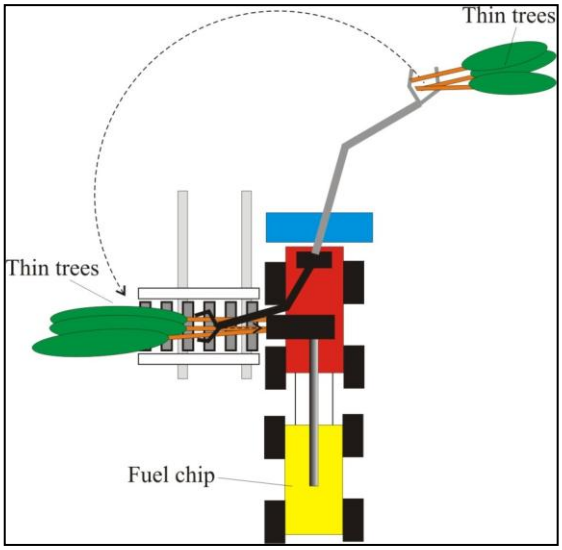

Figure 5. The UTP working with the TT.

The efficiency of the UTP was studied on mathematical models using simulation methods [5, 18, 19].

The hourly productivity of the UTP depends on the type of trees being processed and includes operations for cutting and processing trees into assortments (only for BT) and processing LR, LT, TT into fuel chips.

In the mathematical models, the working operations of the UTP were presented as a queueing systems. The accumulating head, the delimbing-bucking unit and the chipping machine were presented as service devices. The trees are requests for services. Requests are serviced by the devices. The request flow can create queues before service devices, which will affect the overall productivity of the UTP. The hourly productivity of the UTP will depend on the time cycle and on how many requests (trees) at the same time will be served by the servicing devices of the UTP.

The maximum number of the TT in the accumulator head depends on its characteristics. In practice, the number of the TT is usually limited to 3-5, which does not exceed the capacity of the accumulator head. Therefore, in the article, the number of the TT in the head is assumed to be equal to all thin trees within the working zone.

The number of all types of trees within the working zone and their diameter is random and depends, in particular, on the stock of wood.

The number of the BT, LT and TT within the working zone was determined for each zone as a uniformly distributed random number based on the percentage of each tree type. The article takes the following percentages of each type of trees: BT – 40%; LT – 20%; TT – 40%.

The volume of the tree depends on its breed and age. In the model, the volume of the tree was determined by the average value as a random number distributed according to the normal law. In the work, the following average characteristics of trees were accepted: the volume of the BT – 0.3 m^3; the volume of branches and the top (LR) of BT – 0.06 m^3; the volume of the LT – 0.36 m^3; the volume of the LT – 0.04 m^3.

The cycle times of the accumulator head in different operating modes are taken as random numbers distributed exponentially with an average value depending on the mode of operation of the head and in recalculation to one tree.

The time to place the tree in the delimbing-bucking device will depend on the operator's qualification, the location of the tree, and so on. The average time for delimbing-bucking operation was determined by timing.

The time to process branches and trees into the fuel chips will depend on the performance of the chipping machine. This time is taken by the average value as a random number distributed according to the exponential law.

Taking into account the adopted distribution laws, a simulation model of the technological process of the machine was developed, and a plan of experiments was drawn up. In this article, we have taken two independent factors:

1. Type of logging and products produced.
2. The average number of all trees within the work zone.

The experiment planning matrix is shown in table 1.

Table 1. Matrix of experiments.

Option for logging trees	Type of logging and products produced	The average number of all trees within the work zone
1	BT: only assortments	5
1	BT: only assortments	10
1	BT: only assortments	15
2	BT+LR: assortments+chips	5
2	BT+LR: assortments+chips	10
2	BT+LR: assortments+chips	15
3	BT+ LR+LT: assortments+chips	5
3	BT+ LR+LT: assortments+chips	10
3	BT+ LR+LT: assortments+chips	15
4	BT+ LR+LT +TT: assortments+chips	5
4	BT+ LR+LT +TT: assortments+chips	10
4	BT+ LR+LT +TT: assortments+chips	15

3. Results and Discussion

Some experimental results are presented as graphs in figures 6-9.

Figure 6 shows the dependence of the UTP performance when logging trees in option 1 on the number of trees in the working zone. As you can see from the graph in figure 6, the output volume of assortments slightly exceeds the output volume of fuel chips. The productivity of the machine increases slightly with the increase in the number of trees within the working zone, which is explained by a decrease in the share of time spent moving between working zones. The same dependences were obtained for all others options (table 1). All the graphs similar to the curves in figure 6.

Figure 7 shows the dependence of the UTP productivity for assortments on the number of trees within the working zone for all types of logging (all options). The UTP productivity for assortments output was highest in the case of option 2 (table 1). The highest UTP productivity in option 2 compared to option 1 is due to the loss of time to clean up logging residues in option 1, which reduces the UTP productivity. The lowest UTP productivity was found in the case of option 4. The drop in the UTP productivity when switching from option 2 to option 4 is about 40%. When working by the option 1, the UTP performance decreases by about 5% compared to option 2, and by about 30% for option 3.

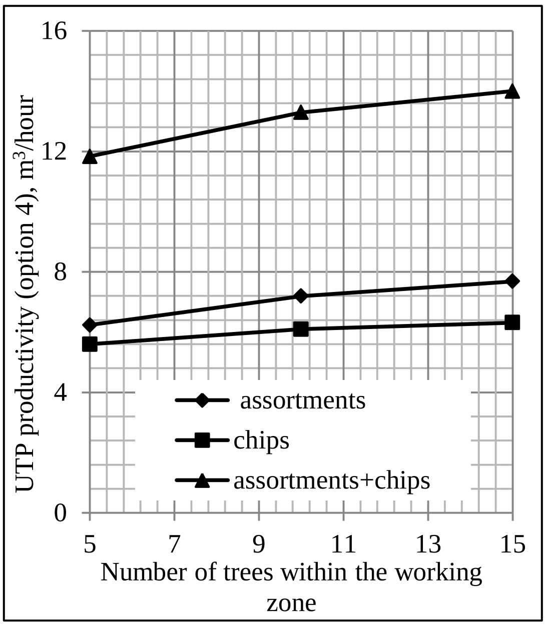

Figure 6. Dependence of the UTP's productivity on the number of trees within the working zone (option 4).

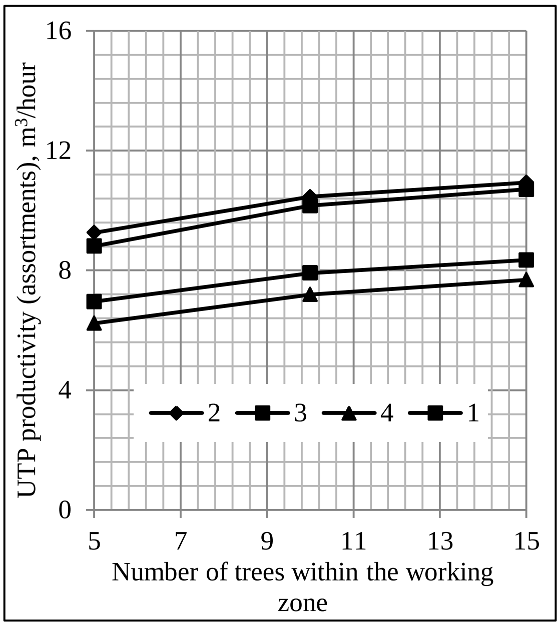

Figure 7. Dependence of the UTP's productivity (assortments) for all options on the number of trees within the working zone.

The decrease in the production of assortments when the UTP is operating under options 3 and 4 is compensated by the production of fuel chips. Figure 8 shows the dependence of the UTP productivity for fuel chips on the number of trees within the working zone for all options. The chips performance of the UTP is greatest in option 3. In this case, all trees are harvested except the thin ones. The UTP chip productivity differences between option 3 and option 4 is small and is 3-5%.

Figure 9 shows the dependence of the UTP productivity for assortments+chips on the number of trees within the working zone for all options. The overall productivity of the UTP will be maximum when it is running by option 3 (table 1). In the case of the UTP operation under option 4, the overall productivity is reduced by almost 10% compared to option 3, due to the longer cycle time of harvesting and processing of thin trees. The lowest overall UTP productivity is occurred when working under option 1, when business trees are harvested and only assortments are produced.

4. Conclusion

The results of simulation experiments on the UTP allow us to write the following conclusions.

1. A universal tractor processor (UTP) is proposed for working in forests of different ages, where there are business (BT), low quality non-commercial (LT) and thin (TT) trees. The UTP allows you to harvest all types of trees and process them into assortments and for fuel chips.
2. This article discusses four options the UTP works (table 1).
3. The maximum productivity of the UTP for the output of assortments (from 8.8 to 10.7 m^3/h) will be in the case of logging BT with the production of chips (option 2).
4. The total productivity of the UTP will be maximum when it is working by the option 3 (from 12.7 to 15.2 m^3/h), when BT and LT are harvested.

In practice, if the goal is to maximize the output of business assortments, then the UTP work should be organized according to the option 1 or 2. If the time to clean up the logging residuals before the UTP is longer than the time to process the residuals into fuel chips, then option 2 will show the best results. In this case, in addition to the maximum output of assortments, additional products will be obtained – fuel chips.

In forests of different ages, the maximum productivity of the UTP for the output of assortments is achieved if you exclude the harvesting of thin-sized trees (option 3). Thin trees can be reserved as undergrowth. In this case, the maximum overall productivity of the UTP for the output of assortments and fuel chips is achieved.

In conclusion, it should be noted that the results obtained have limitations, since they are obtained for a specific distribution of trees and do not take into account the time for transporting the UTP hopper filled with chips to the loading area.

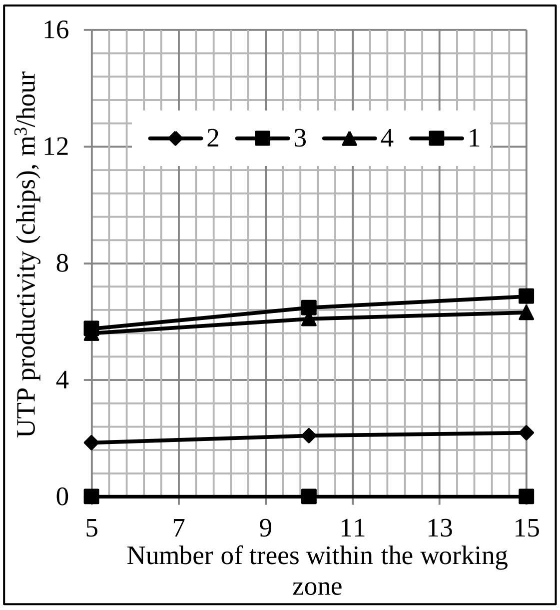

Figure 8. Dependence of the UTP's productivity (chips) for all options on the number of trees within the working zone.

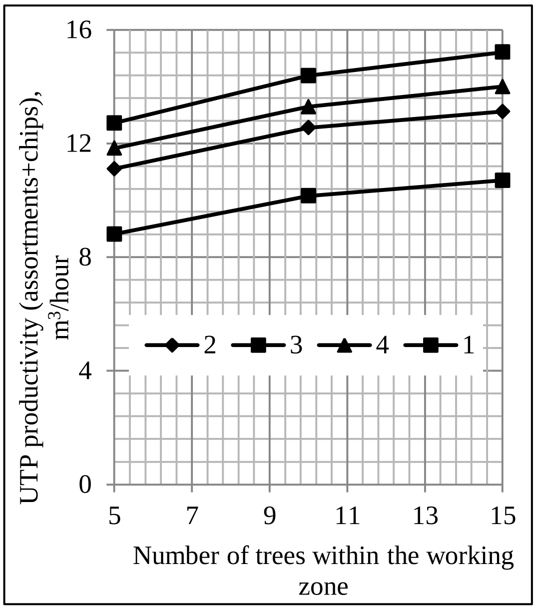

Figure 9. Dependence of the UTP's productivity (assortments+chips) for all options on the number of trees within the working zone.

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