QUALITY CONTROL IMPROVEMENT OF HARVESTERS IN COMERCIAL THINNING

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Abstract. In recent years a trend towards intensification of machine operated logging when performing commercial thinning has been observed in Latvia forestry. By intensifying the logging process when the operators of multi-purpose harvesting machines (harvesters) select the removable trees of the commercial thinning and recording of the work performed, it is carried out by a computerized operation system in a harvester. Quite often a local non-uniformity in the density of the residual stand is observed – closer to the strip roads the harvester operators remove more trees than in the middle of the strip. So this problem is very important in the development of high quality forest stands. The aim of the current research is to offer the harvester a device for recording the number of the trees to be removed, which will help the operator control the regularity of the location of the trees to be removed during the operation thus ensuring also a uniform location of the trees, which are to be left in the stand. A theoretical algorithm of controlling the uniformity of forest stand density for the harvester has been developed in this research and also a structural description of the controlling system device has been made.

Keywords: commercial thinning harvester, uniformity of thinning.

Introduction

The introduction of machine operated commercial thinning in Latvia forestry demands for organization of good quality control of the remaining part of the stand after logging. While the commercial thinning sites were prepared with marking of the trees to be removed in nature, it was relatively easy to determine the quality parameters of the residual stand from which one parameter was the uniformity of the location of the trees to be removed in the territory of the forest stand [1].

By intensifying the logging process in commercial thinning, the trees to be removed are chosen by harvester operators and the recording of the performed work is carried out by a computerized harvester operating system. As a result, non-uniformity in the local density of the residual thinned stand is observed. Focusing on productive logging, harvester operators carry out thinning in a more intensive way along strip roads than farther away from them. In the research conducted during previous years it was proved that the harvester operator when working from the strip road, performing thinning in the half-rows does it non-uniformly. The half-row adjoining the part of the stand, which has already been thinned, is tended better and more intensively, but the half-row, which is located closer to the non-thinned stand, has a worse evaluation [2].

As the aforementioned problem is significant in the technological process of machine operated commercial thinning, the aim of the current research is to find a solution – to offer a device to the harvester for recording the number of the trees to be removed. Using this device, the trees, which are to be removed, are recorded by the forest stand worksite rows. In other words – to offer technically-theoretical substantiation for the device which could help control the quality of the harvester operator's work, ensuring uniform location of the residual trees in the forest stand.

Materials and methods

The topicality of the problem mentioned in the introduction has been approved by the research carried out in 2008, 2009 and 2011 in 24 different commercial thinning sites, which have been thinned by harvesters in geographically different locations of Latvia – in the territories of Zemgale and Vidusdaugava forestries of the SJS company LVM. Additional observations were carried out when in the strip of a forest stand between two adjoining strip roads eight-strip sample plots were established (Fig. 1).

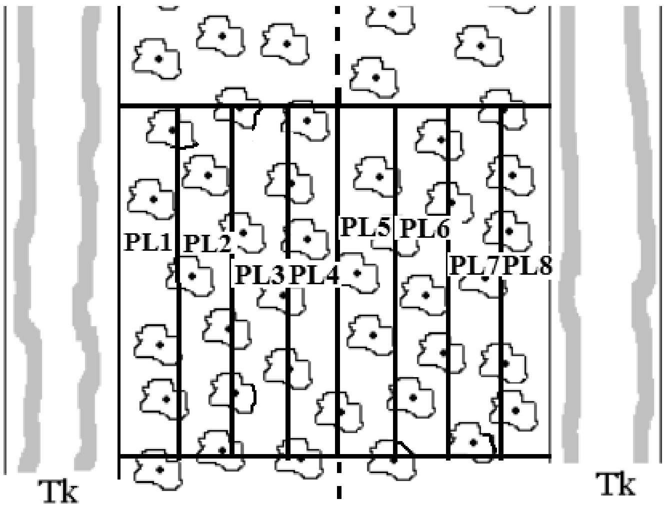

Fig. 1. **Layout of sample plots in the felling site and its distribution into strip roads**

The number of residual trees was also upgraded by 2.0 m wide strips, extending parallel to the longitudinal axis of the strip road (Table 1). Carrying out a one-way analysis of variance (ANOVA) statistical information was obtained (Table 2).

Table 1

Distribution of remaining trees by 2 m wide strips

between two adjoining strip roads

Site Number	**Average number of trees per ha. in sample plots**							
	PL1	**PL2**	**PL3**	**PL4**	**PL5**	**PL6**	**PL7**	**PL8**
1	640	677	832	977	910	733	596	575
2	842	890	1094	1284	1500	1209	982	947
3	664	702	864	1013	915	737	599	577
4	963	1018	1252	1469	1291	1040	845	815
5	914	967	1189	1395	1146	923	750	723
6	665	703	865	1014	882	711	577	557
7	738	780	959	1125	1026	826	671	647
8	750	793	975	1143	1229	990	805	776
9	683	722	888	1041	933	752	611	589
10	832	879	1081	1268	1116	899	730	704
11	537	568	699	819	764	615	500	482
12	834	881	1084	1271	1116	899	730	704
Average pcs·ha^{-1}	755	798	982	1152	1069	861	700	675

The results in Tables 1 and 2 show that it is necessary to integrate the control adjustments into the harvester operating system, thus allowing it to record the location of the trees to be removed in relation to the strip road. Theoretically feasible control algorithm of the location of the remaining trees after performing the commercial thinning of the stand may be based on the following assumptions:

1. Initial location of the trees in the felling site is uniform;
2. Trees to be removed are located between the trees to be left for growing in the felling site;
3. Harvester operator in each pit stop – on the strip road thins both strips close to the forest stand and both sides of the middle strip (Fig. 2);
4. in one pit stop the number of the removed trees is proportional to the area which can be thinned by the boom (head).

Taking into account the assumptions mentioned above, the harvester boom has been observed in the horizontal plane of the work zone (Fig. 2) for theoretical substantiation.

Table 2

Anova for remaining trees between adjoining strip roads

Groups	Number	Sum	Average	Variance
PL1	12	9062.000	755.167	15526.952
PL2	12	9578.534	798.211	17347.471
PL3	12	11781.597	981.800	26244.989
PL4	12	13819.813	1151.651	36111.241
PL5	12	12826.951	1068.913	42609.048
PL6	12	10333.482	861.124	27653.386
PL7	12	8394.380	699.532	18248.712
PL8	12	8094.870	674.573	16969.721

Source of Variation	SS	df	MS	F
Between Groups	2603320	7	371902.858	14.823
Within Groups	2207827	88	25088.940	–
Total	4811147	95	–	–

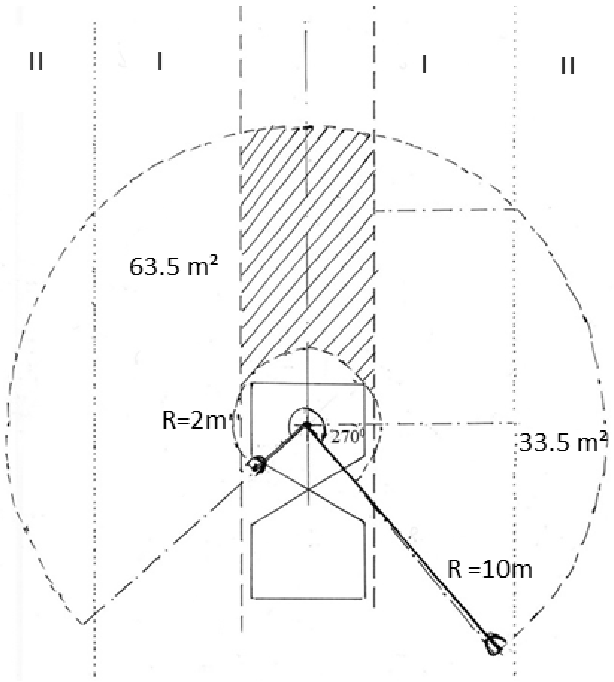

Fig. 2. **Work zone of harvester boom in horizontal plane**

From technical specifications the shape of the work zone of the harvester boom is 270º of a full circle with a maximum radius of 10.0m, minimum work radius of 2.0 m and symmetrical to the strip road longitudinal axis. Using the common formula of the area of a circle, the total area of the work zone (S) is as follows:

$$S = (\pi \times R^2 \times 0.75) - (\pi \times r^2 \times 0.75) \quad (1)$$

where $\pi = 3.14$;
R – maximum boom reach, m;
r – minimum boom reach, m;
0.75 – coefficient, characterizing the angular parameter of the work zone.

The calculations show that the total area S equals to 226 m^2, but in that part of the work zone where the strip road will be established all the trees are envisaged for cutting, thus, from the point of view of the residual stand, it can be excluded from the total area "S". It means that in the work zone where a uniform location of the remaining trees should be ensured, *Sd* can be calculated according to the following formula:

$$Sd = S - Stk, \quad (2)$$

where

$$Stk = 4 \times (R - r). \quad (3)$$

As a result $Stk = 32$ m^2 and Sd= 194 m^2. As in commercial thinning the harvester works on both sides of the strip road, $Sd / 2 = 97$ m^2.

In 1976 T. Roziņa pointed out that the most suitable trip for the boom – type of harvesting machines is a trip which coincides with the length of the base machine (3-5 m). With such trips it was possible to reach 92 % of the trees to be removed [1]. This parameter was a real achievement in the 80s of the 20th century, but nowadays it does not meet the forestry requirements of commercial thinning.

Projecting the image of Figure 2 on Figure 1, it can be seen that the cutting of trees is performed both, in the first strip and in the half of the middle strip of the forest stand. Using the formulae of geometric shape area determination – in the strip 1, the work zone area can be determined as a complicated sum of areas "s1", but the work area in the middle strip as a difference of:

$$S2 = (Sd / 2) - S1 \quad (4)$$

The calculations show that:

$S1 = 63.5$ m^2 and $S2 = 33.5$ m^2.

Taking into account the assumptions mentioned above, concerning the uniform location of the trees to be removed in the felling site, the work zone relation by strips will be preserved also in the proportion of the number of the trees to be removed:

$S2 / S1 = 33.5 / 63.5 = 0.53$ or vice versa (1.89).

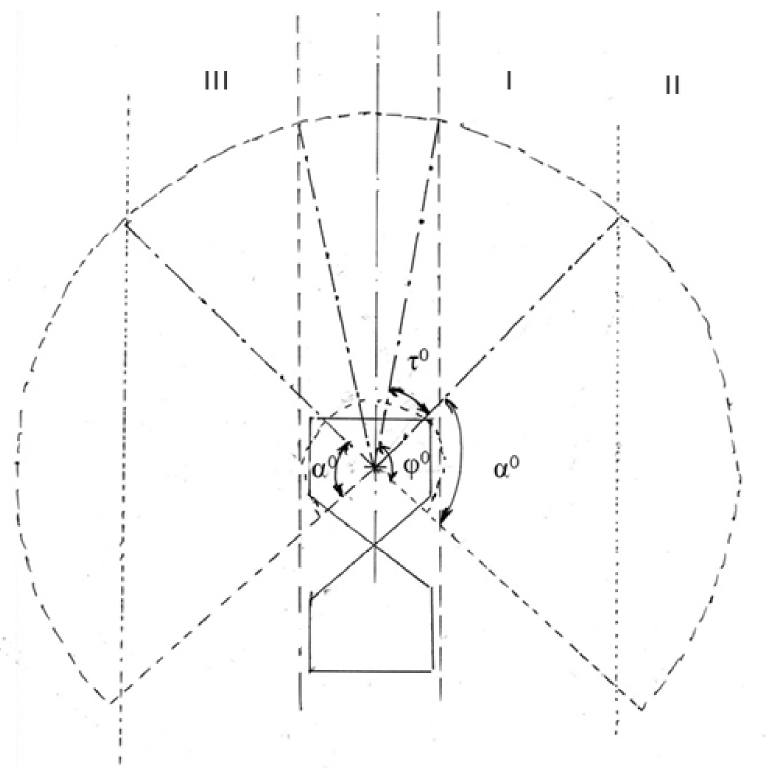

Fig. 3. **Angular control scheme of boom in horizontal plane**

At each harvester pit stop in the strip adjoining the technological strip, the number of removed and processed trees (from 2.0 m to 7.0 m of boom position) should be 1.89 times more than in the half strip of the farther work zone middle part. Controlling the above mentioned relationship it could be achieved that the number of trees per unit of area (e.g., 100 m^2) will be identical in all the strips and the number of the remaining trees in all the strips between the strip roads will be close to identical. In this way it is possible to ensure a uniform location of trees in the thinned forest stand.

Taking into account the conclusion that the level of 92 % of accessibility of the trees to be removed can be achieved, when the harvester pace along the strip road is with the distance 5-6 m, it is possible to reach a condition, when the non-thinned area between two adjoining work zones in the horizontal plane (Fig. 3) makes up 0.5 m^2, and the probability that there is a tree to be cut is 5 %.

Basing on the procedure of the theoretical calculations, a harvester operation control system is offered which will enable the harvester operator and work receiver to better control the principle of uniform location of the trees to be left in the thinned stand.

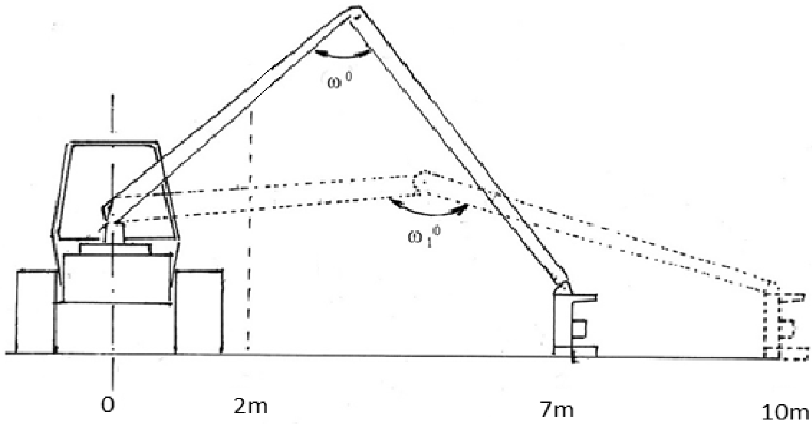

Fig. 4. **Distance control scheme for boom in vertical plane**

Results and discussion

Constructive description of the control system.

The control system in the boom includes two control sensors:

- angular control sensor, type - potentiometer;
- boom reach control sensor, type - potentiometer.

The angular control sensor is fixed to the boom head non-movable part and transmits a signal to the receiver which is fixed to the movable columns (Fig. 3). The boom reach control sensors are attached to the folding location of the boom and the farthest point of the telescopic section (Figure 4). As a result, when controlling the boom turn angle and boom parameter the work zone is calculated where the tree to be cut is located. For instance, if the harvester working head is within a range of angle τ (Fig. 3) and the boom 2.82-7.0 m, the tree to be cut is located in the adjoining strip. As soon as the boom reaches the angle α at the boom reach 7.0-10.0 m (ω_1-ω) (Fig. 4), the tree felling is carried out in the middle strip. The same happens when the boom is in the angular sector like in a mirror image strip road opposite side. The information collected can be integrated in the harvester on-board computer or supplement the operating control system with a calculating device.

At this moment the control of the compliance with forestry requirements takes place after completing the logging process, and the obtained information has a nature of findings. To improve and correct the detected shortcomings, the necessity to return to the initial phase of the work process emerges, which significantly raises the cost and prolongs the technological process of logging. By introducing such a device, the uniformity of the trees to be removed would be controlled directly during the logging process, and it would not be necessary to return to the parts of the thinned stands "to make improvements and corrections" of the logging intensity.

The recording of the removable trees in the designated parts of the felling site described in the current research is actually not an innovation in the sector, since the software of harvesters allows carrying out the recording of the coordinates of each individual removable tree which is stored in the harvester computer "PRI" files. The principle is as follows: from the harvester GPS receiver the coordinates are given at each tree removal and the harvester computer stores them together with the dimensions of the line segments of the bucked stem. In order to use these technical possibilities in the current research, an accurate digital technological scheme of the felling site would be required with precisely electronically defined strip roads in it. A problem could emerge with regard to the accuracy of the currently used GPS devices installed in harvesters, since ±3 m could be a big mistake for caring out this job and as a result the practical purpose of this system would be lost.

For the innovation of this research to be more effective, apart from the recording of the row identity of the removable trees, it would be necessary to record the diameter of the trees to be removed. By means of formulae it could be possible to calculate which part of the basal area is being cut in a definite segment. This information should be constantly available to the harvester operator during the work performance. This would increase the quality of the work performed.

Conclusions

1. The device offered to harvester operators will ease the control of the work quality. By ensuring more uniform location of the trees to be left, the quality of the thinned stands will increase.
2. It will be easier for the logging foremen to control the condition of the residual stand according to the data recorded by the device. This, in turn, will reduce the possibilities of arguments about the quality of the thinned stand.
3. Technical managers will be able to control the intensity of the loading of the harvester boom according to the recorded data provided by the device.
4. In addition to the major quality parameter of the thinned stand "basal area", it will be possible to control "the density uniformity" of the thinned stand.

References

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