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Experimental substantiation of the effectiveness of the use of a harvester and forwarder in working conditions in cutting areas with broad forest swathes

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Abstract

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The article is devoted to the analysis of the results of experimental studies of shelterwood felling technology using technological schemes with broad forest swathes. Experimental studies were conducted using three different technological schemes with broad forest swathes and a harvester for tree felling. The collection of experimental data was conducted in the form of a two-factor experiment with three levels of variation for each factor and a proof by exhaustion. Research objective: identification of theoretical patterns of logging using a harvester and forwarder for shelterwood felling in cutting areas with broad forest swathes in various natural and production conditions of the developed cutting areas. The results obtained made it possible to assess the potential for reducing the number of trees cut for forwarding trails when carrying out shelterwood felling and to analyze the performance of the harvester for various technological schemes of work on cutting areas with broad forest swathes.

Keywords: cutting area work; harvester; forwarder; logging work; technological corridor; swath

Introduction

Increasing the width of forest swathes reduces the environmental impact of logging. However, this can lead to a decrease in the productivity of forestry machines and mechanisms when performing shelterwood felling (Laptev, 2018; Laptev and Matrosov, 2018). In the pursuit of economic efficiency, enterprises are often not interested in implementing little-studied technological solutions that can lead to a decrease in production efficiency. An informed choice of effective technology is needed. It should consider both the positive and negative aspects of each option for logging operations (Rukomojnikov, 2015; Rukomojnikov et al., 2017, 2022a, 2022b) and the interests of both logging and forestry organizations.

Theoretical studies of harvesting technology using a harvester and forwarder (Rozhkov et al., 2018; Petelina and Maslov, 2008; Laptev, 2014; Azarenok et al., 2012) make it possible to compare the option of harvesting in cutting areas with broad swathes and the option of harvesting in cutting areas with narrow swathes, which is traditionally used on the cutting areas of Training-Experimental Leshoz of the Volga State University of Technology and most enterprises of the Russian Federation.

The experiment described in the article presents a range of problems, and potential solutions include conducting a multivariate experiment with an analysis of all possible combinations of the main factors (Krutov et al., 1989).

Materials and Methods

Currently, the most studied technology for cutting operations using a harvester and forwarder is the technology for

Table 1. Levels of variation of factors

Analyzed factors	Levels of variation of factors:								
	in the analysis of basic technology with narrow forest swathes			in the analysis of cutting areas with wide forest swathes with one technological corridor between forwarding trails (figure 1, 2)			in the analysis of cutting areas with wide forest swathes with two technological corridors between forwarding trails (figure 3)		
	-1	0	+1	-1	0	+1	-1	0	+1
The width of the forest swathes, meters	12	13,5	15	24	27	30	35	40	45
Harvester operator №	1	2	3	1	2	3	1	2	3

Source: Authors' own elaboration

developing cutting areas with narrow forest swathes. Technologies for developing cutting areas with broad swathes can significantly reduce the negative environmental consequences for the remaining trees after selective felling. However, technologies for developing cutting areas with broad swathes are less commonly used. For them, there are no recommendations for marking the borders of swathes in various natural and industrial conditions, nor are there experimental justifications for the effectiveness of using forestry machines.

Research objective: identification of theoretical patterns of logging using a harvester and forwarder for shelterwood felling in cutting areas with broad forest swathes in various natural and production conditions of the developed cutting areas.

The collection of experimental data was conducted in the form of a two-factor experiment with three levels of variation for each factor and a proof by exhaustion. Levels of variation of factors are presented in the form of a digital matrix (Table 1). All observations were conducted for three groups of harvesters and forwarders operators. This was done to ensure the purity of the experiments and to justify the share of influence of the width of forest swathes and the qualifications of the workers on the results.

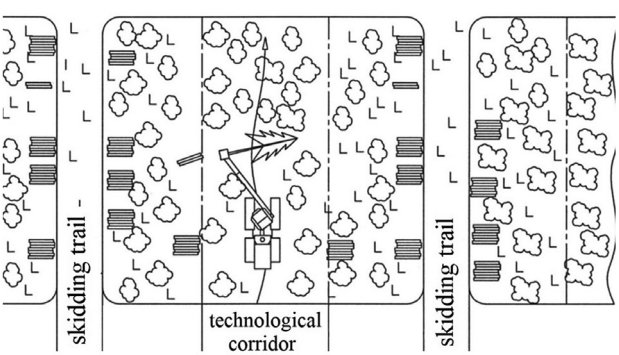


Fig. 1. Cutting area with wide forest swathes with one technological corridor between forwarding trails (Variant of technological scheme №1)
Source: (*Laptev, 2014*)

Figures 1 and 2 show two versions of the Cutting area with wide forest swathes, with one technological corridor between forwarding trails. Figure 3 shows the Cutting areas with wide forest swathes with two technological corridors between forwarding trails.

The statistical design of the experiment, with a complete enumeration of options when checking three technology options with broad swathes at three levels of variation of two factors, has 27 fixation points.

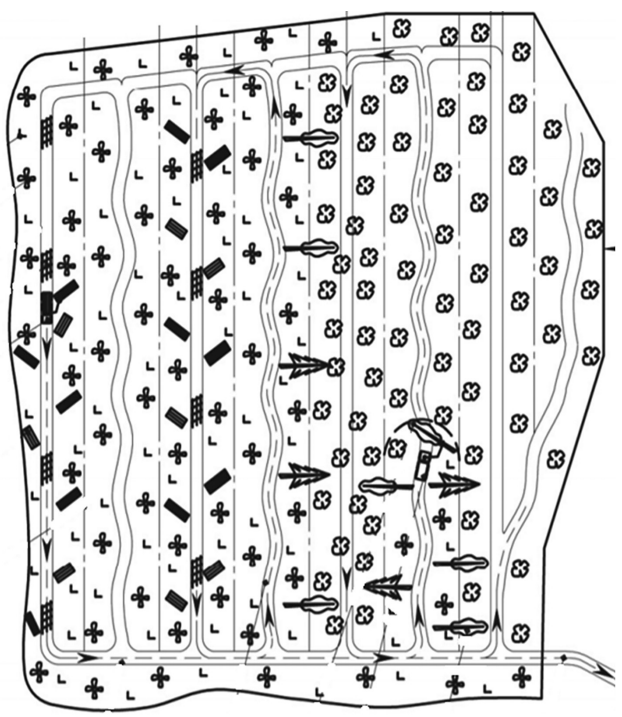


Fig. 2. Cutting area with wide forest swathes with one technological corridor between forwarding trails (Variant of technological scheme №2)
Source: (Rozhkov, Eroshkina, Klysh, Malashevich & Protas, 2018)

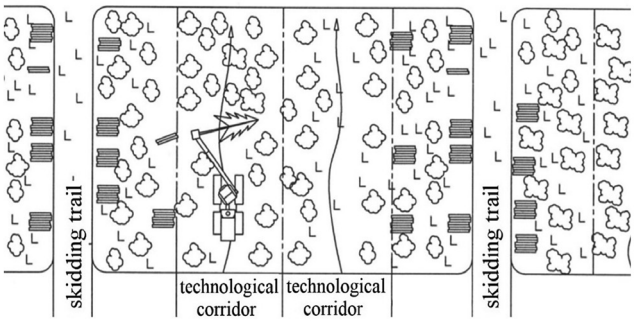


Fig. 3. Cutting areas with wide forest swathes with two technological corridors between forwarding trails (Variant of technological scheme №3)
Source: (*Laptev, 2014*)

Results

Figure 4 illustrates the effect of harvested tree volumes on harvester productivity. This was done to visually present the resulting totals of the average hourly productivity of the harvester.

An analysis of the presented graphs confirms the assumption that with an increase in the average volume of a tree-length in cutting areas, there is an increase in the productivity of the harvester when using any of the compared technological schemes. Graphs provide a visual representation of the harvester's performance in various natural cutting conditions.

The revealed results of the influence of changes in the width of forest swathes at different volumes of harvested trees on the hourly productivity of the harvester are shown in Figure 5.

An analysis of the graphs reveals a significant decrease in the productivity of the harvester with an increase in the width of the developed apiaries. Increasing the width of swathes by 25 percent compared to the minimum width of swathes used in the experiments makes it possible to say that this reduces the productivity of the harvester by about 10 percent. This is most evident in areas with a small average volume per tree.

Harvester shift performance analysis results are shown in Figure 6.

Analysis of the graphs shows that the most productive variant of the wide forest swath technology is the variant of the technological scheme No. 1 with one technological corridor between forwarding trails. The next most effective is the variant of the technological scheme No. 2. The least effective in this indicator is the variant of technological scheme No. 3, which features two technological corridors between forwarding trails.

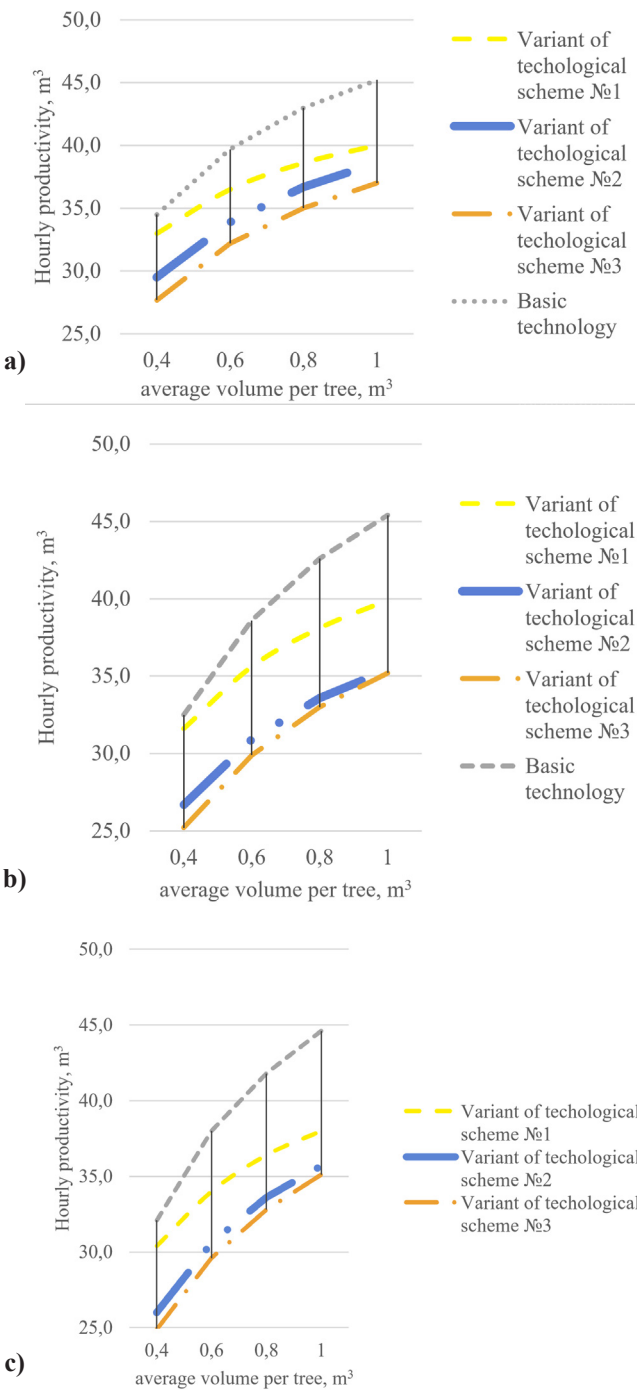


Fig. 4. The influence of harvested trees volumes on the harvester's hourly productivity under the conditions of using various technological schemes for developing cutting areas with wide forest swathes at the level of varying the width of forest swathes a) -1; b) 0; c) +1.
Source: Authors' own elaboration

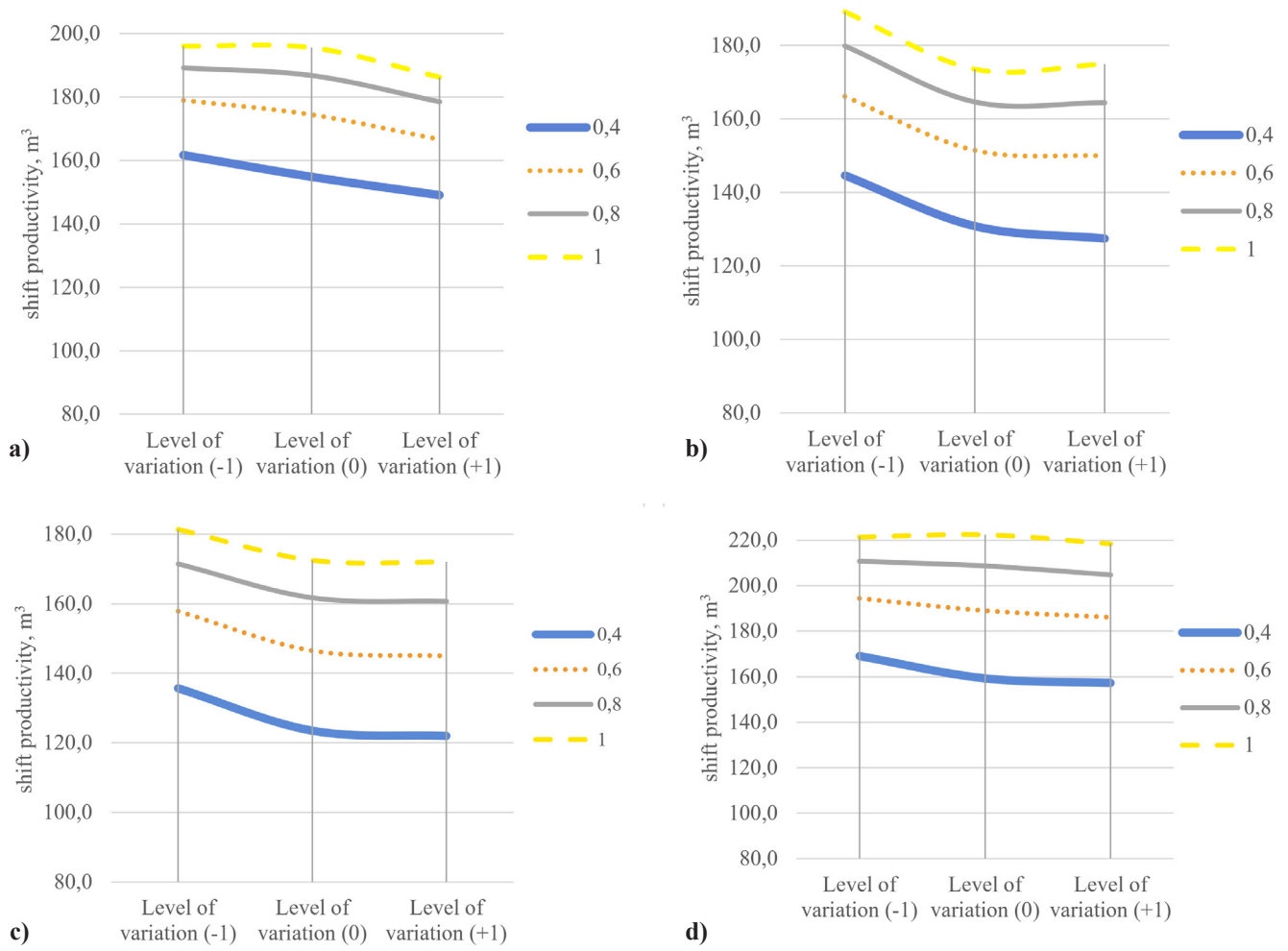
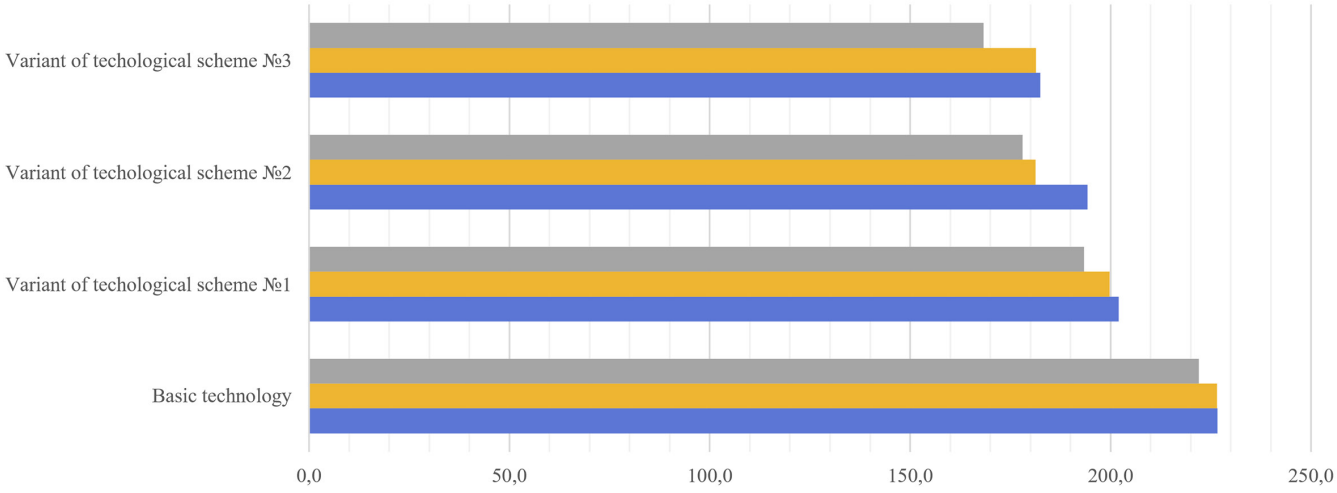


Fig. 5. The effect of changing the width of the swath on the harvester productivity per shift under working conditions at different average volumes of harvested wood in the cutting areas: a) variant of technological scheme №1; b) variant of technological scheme №2; c) variant of technological scheme №3; d) basic technology with narrow forest swathes.
Source: Authors' own elaboration

Discussion

The performed studies represent a new stage of research in the field of developing technological schemes for cutting areas, which enables the reduction of skidding trails within the cutting area. None of the previous studies aimed to experimentally compare a wide range of forest swath technologies for working in the forest according to the criterion of harvester performance (Rozhkov et al., 2018; Laptev, 2014; Aksenov et al., 2015; Mohirev, 2015). Until now, the primary focus of researchers has been on the theoretical study of the development of cutting areas with broad forest swathes and the creation of mathematical models to calculate their efficiency. Comparing the theoretical research results obtained earlier by other scientists noted in the article (Petelina and Maslov, 2008; Azarenok et al., 2012) with the presented new experimental research results, one can note a relatively high degree of convergence of the final results of the harvester performance when analyzing the influence of the average volume per tree. At the same time, this article provides a clear demonstration of the importance of the fact that other researchers did not consider the reduction in harvester productivity resulting from the increase in the width of developed forest swathes.



	Basic technology	Variant of techological scheme №1	Variant of techological scheme №2	Variant of techological scheme №3
Levels of variation (+1)	222,0	193,4	178,0	168,3
Levels of variation (0)	226,6	199,8	181,3	181,4
Levels of variation (-1)	226,7	202,0	194,2	182,5

Fig. 6. Influence of the width of forest swathes on the shift productivity of the harvester during selective felling in cutting areas with wide swathes
Source: Authors' own elaboration

Conclusion

The analyzed technologies for working on cutting areas with broad forest swathes can reduce the share of trees being cut down and increase the safety of forest undergrowth by reducing the number of forward trails on the cutting area. However, experimental studies on shelterwood felling show a decrease in harvester productivity for all three analyzed technological schemes of work on cutting areas with broad forest swathes compared to the basic version of work on cutting areas with narrow forest swathes. The results can be utilized by forestry enterprises when designing work technology using multifunctional logging machines in various natural conditions of logging sites. One option for further elaboration of the topic presented in the article is to conduct similar studies for other logging machines and develop new technological schemes that enable increasing the width of developed forest swathes.

Acknowledgments

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