

ICEST 2021**II International Conference on Economic and Social Trends for Sustainability of Modern Society****ECONOMIC EFFICIENCY OF CARE CUTTING EQUIPMENT
MODERNIZATION**

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Abstract

The timber industry is an integral part of the Russian economy. Forests cover more than half of the country's territory, but the share of the forestry sector in the gross domestic product (GDP) is only 1.3%. This situation testifies not only to the low efficiency of forest harvesting, but also to the insignificant effectiveness of forest care measures. In this regard, it is important to develop such measures and devices that would increase the economic efficiency of timber harvesting. There are many ways to care for forests, among which thinning plays an important role. They allow not only to remove unwanted plantings, but also to use them additionally, for example, as fuel briquettes. On this basis, it is important to develop such a thinning device that will combine high throughput, environmental friendliness, ease of maintenance and high productivity. Thinning today uses either large machines such as harvesters and skidders, or motorized hand tools such as motorized hedge trimmers or petrol powered saws. The first option is not environmentally friendly and labor-intensive, since machines destroy healthy undergrowth, unnecessarily compact the soil, and also require skilled workers. The second option is ineffective and traumatic. The development of an eco-friendly, sandless tree shredder with small dimensions and high performance is urgent. The operation of such a device requires less economic investment, since the work is performed by one operator.

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Keywords: Timber thinning, labor mechanization, grinding wood without grinding



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1. Introduction

Forestry felling is the most important forestry activity aimed at the formation of stable highly productive economically valuable plantations, the preservation and enhancement of their useful functions and the timely use of wood. They are carried out by removing unwanted trees from plantations and creating favorable conditions for the growth of the best trees of the main species (Ministry of Nature of Russia, 2017).

The following types of felling are distinguished: clarification, cleaning, thinning, passage felling, renewal felling, re-forming felling, landscape felling, selective sanitary felling.

2. Problem Statement

Thinning is an effective reforestation operation. Large-sized machines, such as harvesters, skidders, are mainly used in felling (Kondratyuk, 2016). They have high productivity, but their use in young and middle-aged forests does more harm than good. The machines are large and often destroy healthy undergrowth and small trees and unnecessarily compact the soil with their weight. The use of a manual mechanized tool is advisable with a large density of plantations, but it is characterized by low labor productivity. In addition, there is a need to deliver the brigade to the site of felling, additional organization of accommodation for workers (Gerts & Terinov, 2019). The main disadvantage of felling with the help of large-sized machines and manual power tools is the need to deliver the felled trees from the felling site to the warehouse. These are additional economic and time costs. In this regard, there is a need to develop a device that is able to combine the efficiency of the harvester and the maneuverability of a person. At the same time, it is also important to solve the problem of utilization of felled plantations in order to exclude their transportation to the place of storage.

3. Research Questions

According to research by Puzanova and Smolina (2019), the Krasnoyarsk Territory is one of the leaders among the regions of Russia in terms of forest resources, therefore it is strategically important here to maintain a balance between felling and restoration. The area of its forest fund is 168.1 million hectares, of which 69% of the territory is forested. Forests are 88% coniferous. In terms of species composition, more than half of the forests are represented by larch. About 17% are spruce and fir, pine - 12%, cedar - 9%. Every year, reforestation activities are carried out on the territory of the Krasnoyarsk Territory on an area of 50.4 to 57.0 thousand hectares. Forest cultures are being created on forest fund sites from 4.8 to 7.3 thousand hectares. Measures are being taken to promote natural forest regeneration on an area of 45.5 to 49.8 thousand hectares. As a result of work on forest reproduction, land covered with forest vegetation on an area of 77.6 to 83.6 thousand hectares is carried out, which allows ensuring a balance between forest felling, forest fires, other negative impacts and reforestation.

Russia has a wide variety of resources, one of which is the forest. The forestry sector of the economy occupies an insignificant part of the country's economy (1.3% of GDP). This indicates the ineffective use of forest potential (Sokolov et al., 2019).

Taking into account the low efficiency of forest use in Russia, it is necessary to choose a type of reforestation that, at minimal cost, will provide good results in the long term.

Thinning can be seen as one of the most effective methods of reforestation. It requires a minimum inclusion of additional equipment or even the use of forestry machines. No different fertilizers or specially grown trees are required.

4. Purpose of the Study

The study compares the economic costs of using a shaftless tree chopper and a power tool to determine the most efficient thinning method, not only in terms of productivity and ecology, but also economy.

5. Research Methods

Schwartz et al. (2019) Believe that one of the reasons for the low efficiency of thinning in forestry is the unsettled system of measures for forest maintenance, a great variety and lack of orderliness in the use of thinning equipment. This leads to additional costs for equipment maintenance and labor organization. It is very important to carry out thinning of the forest, because in the long term they allow to improve the quality of the grown timber, increase the growth of timber per unit area, improve the sanitary situation in the forest and realize many other useful functions of forests.

When choosing equipment for cutting, it is necessary to be guided by environmental and economic indicators. If thinning is carried out using large-sized machines, there is a risk of damaging growing and healthy young trees, as well as unnecessarily compacting the soil. When cutting with harvesters, it is necessary to take the removed trees to a warehouse and process them. This increases the cost of such an operation.

In the case of thinning with a manual motorized tool, for example, a motorized hedge trimmer, labor productivity is reduced in comparison with machine felling. At the same time thinning is more environmentally friendly. A person removes damaged trees more thoroughly and accurately. With a high density of plantations, the worker will do less damage to the trees, since he is more mobile. When thinning with a hand motorized tool, it is necessary to deliver a team of workers to the cutting site and organize additional accommodation and food points for them, which adds cost to the felling process. After thinning with motorized hand tools, the removed trees must also be delivered to the warehouse or immediately processed.

The existing equipment for grinding small-sized trees and felling waste is quite diverse. It includes mechanisms with both internal combustion engines and electric motors, as well as driven from the power take-off shaft of a wheeled tractor. Mechanisms for crushing felling residues can be mounted, trailed or stationary. Cutting products can be scattered, fed into the car body, collected in a special container.

Usually, when processing wood, special shredders are used. As a rule, they require a stationary location or are fixed in the body of trucks. Among such devices, one can single out a disk chipper with the ability to attach it to various vehicles (Syromyatnikov et al., 2017). There is a way to remove felling

residues, which involves the use of a modernized forwarder trailer. When collecting trees, they are sorted, then processed into chips using a rotary knife mill (Zyryanov et al., 2019).

It is important to take into account that wood processed into chips should not be left in heaps in a felling area or warehouse, as it is a factor that increases the fire hazard. It is necessary to immediately send it for further processing. However, wood chips can be left in the forest as fertilizer.

An integrated approach, which involves removing trees by harvesters, transporting them to a warehouse with skidders and then chopping them in a chipper, has a number of advantages. For example, high performance. With a high density of plantations, large-sized equipment becomes less mobile and causes significant environmental damage. This thinning method requires significant financial investments.

In this situation, it is necessary to use such a device in operation that will combine good cross-country ability, high productivity, maneuverability, efficiency and good environmental characteristics. The main environmental characteristics are the minimum possible compaction of the soil under the weight of the equipment and accuracy in work, which allows you to minimize or exclude runs over healthy undergrowth.

Consider the characteristics of the subject of labor. Basically, when choosing, an economic and biological classification is used in accordance with which trees are divided into I - the best, II - auxiliary (useful), III - unwanted (to be removed). Externally, defects can be divided into the following categories: bimodality, butt curvature, trunk curvature, knotty, apex curvature and the presence of stepchildren (Mishchenko, 2019). Such a classification takes into account the sum of economic and biological indicators for assigning a tree to a certain category. In addition, each category uses additional classifications according to G. Kraft (Ipatov, 2010), Nesterov (1961), V. Shedelin (Melekhov, 2003). When felling, it is necessary to strive for leveling the vertical structure of the stand and for an even distribution of plantings over the entire area of the site (Danilenko & Sukhikh, 2019; Markovsky & Rodionov, 2018).

Larch, pine and spruce from grade II to IV are the most common tree species in the forests of Eastern Siberia. Consider the geometric parameters of these types of trees, presented in Table 1. The maximum diameter at the height of the chest is taken 20 cm (Groshev et al., 1980).

Table 1. Geometric parameters of Siberian conifers of the II ... IV categories

Breed	Bonitet					
	II		III		IV	
	height, m	volume, m ³	height, m	volume, m ³	height, m	volume, m ³
Larch	23	0.360	20	0.320	17	0.280
Spruce	21	0.320	19	0.294	17	0.268
Pine	21	0.300	19	0.282	17	0.264

Assuming the density of spruce 550 kg/m³, pine - 600 kg/m³, and larch 700 kg/m³, we determine the mass of trees by the following formula:

$$m_i = V_i * \rho_i,$$

where V_i is the volume of the tree, m³,

ρ_i - wood density, kg/m³.

We will also determine the weight of the plantings by multiplying the mass by the acceleration of gravity. We will summarize the obtained data in Table 2.

Table 2. Weights and weights of Siberian conifers of the II ... IV categories

Breed	Bonitet					
	II		III		IV	
	mass, kg	weight, N	mass, kg	weight, N	mass, kg	weight, N
Larch	252	2475	224	2200	196	1925
Spruce	176	1728	161.7	1588	147	1447
Pine	180	1768	169.2	1662	158	1555

The larch with a height of 23 m has the greatest weight when a tree with a diameter at a chest height of 20 cm falls, which corresponds to the II category and the weight of a tree is 2475 N. In accordance with this, it is necessary to select such a basic machine that, taking into account the weight of the working equipment, will carry out thinning, satisfying all safety standards.

Taking into account the fact that the trees to be cut must be transported and disposed of, it is rational to offer such a device that will simultaneously cut and chop the removed tree.

As the base machine, the Bobcat T770 mini-tracked loader with a shaftless wood chipper as a working body is adopted (Orlovsky, 2018), shown in Figure 1.



Figure 1. Bobcat T770

The loader has a caterpillar track. This makes it stable on both clayey soil and rocky roads. The hydrostatic transmission increases its flotation even when fully loaded. The boom of the machine rises to a height of 3.3 m, which makes it possible to bring the attachment to the tree in a convenient position, even on a small slope. The cabin, which is protected by glass and metal bars, allows for safe felling in high density stands. It will also exclude the accidental hit of the severed parts of the tree in a person and injury.

The main characteristics of the machine are the rated lifting capacity, which is 1611 kg, and the tipping load equal to 4602 kg. This makes it possible to freely use the shaftless devices for thinning and lay the reserve of power for tipping the tree (NAC Machinery, 2021).

The shaftless grinder is an open cylindrical casing in which a logarithmic knife is installed at an angle to the shaft. The device is equipped with a hydraulic gripper and pressure rollers. The cutting disc has a maximum diameter of 25 cm in order to penetrate completely into the wood.

The chopper is powered by the hydraulic system of the base machine.

The work cycle looks like this:

- The tree for removal is selected.
- The approach and aiming of attachments is made.
- The tree is captured.
- Cutting and chopping wood.
- Moving to the next tree.

The cycle time is 1.5 minutes. This time consists of the following operations: boom lift - 4 seconds, lower 2.9 seconds, tilt the attachment - 2.3 seconds, return to home position 2.1 seconds, tree grab - 7 seconds. To determine when to cut and chop a tree, you need to know the height of the trees. Let's take this indicator equal to 23 meters, because according to the range of stands selected for felling, this height is maximum. The cutting speed of the device is 0.53 m/s. Hence, it follows that the time spent on cutting plantings is 43 seconds (Orlovsky, 2018). The cycle includes moving from one tree to another. The speed of the base machine will be 4 km/h or 1.11 m/s, the distance from one tree to another will be 20 m. We will also take into account the need to select a damaged tree and set aside another 30 seconds for this operation. This gives us a total cycle time of 91.3 seconds or 1.5 minutes.

The main criterion for comparing the operation of a shaftless chopper and a gasoline-powered saw is the cost of thinning, including the wages of workers. The calculations are based on the average market salary of 50 thousand rubles. for forest machine operators in logging.

In the case of machine felling, only the driver of the base machine is involved in the thinning process. The attachment not only chops down, but also chops up the tree. Other workers are excluded from the technological process.

In thinning with the use of a manual mechanized tool, a 6th grade feller, a lumberjack and a 4 grade crosscutter are involved.

A 6th grade feller, in turn, performs the following actions: preparation of the workplace, felling trees, moving from tree to tree, refueling the gasoline-powered saw with fuels and lubricants during the shift, monthly maintenance of the gasoline-powered saw.

A 4-grade lumberjack is engaged in pruning branches along the entire length of a felled tree, pruning tops, moving from a whip to a felled tree, refueling the saw with fuels and lubricants and routine maintenance during the shift (Ministry of Health of Russia, 2006).

The binder of the 4th category chops trees with a petrol-powered saw and spreads felling residues.

The calculation of wages with the designation of the actions performed is presented in Table 3.

The work period is 6 months (from May to October). The annual volume of work under the design option will be equal to 8873 m³. The output per person-day with the use of a shaftless wood chipper will amount to 84.5 m³, which is 16.5 times higher than the output by machine-hand tools. Mechanized thinning is more efficient than machine-manual thinning, since the same amount of work will be done much faster.

It is important to note that with mechanized thinning, one worker is involved, while with the use of chainsaws, several people.

Another factor showing the effectiveness of the machine method is the cost of 1 m³ of timber obtained during felling. When using a shaftless grinder, the cost per 1 m³ will be 249.13 rubles, which is 3.2 times lower than the cost of the method using chainsaws. The projected thinning method is more preferable taking into account possible unfavorable weather conditions.

Table 3. Calculation of wages

Technological operation	Rank	Time rate man- h / m ³	Salary, rub.	
			1 hour	1 m ³
Basic variant				
Felling of trees with petrol-powered saws				
- feller	6	0.1545	274.05	42.34
- lumberjack	4	0.1545	205.62	31.77
Pruning branches in the felling area				
- brancher	4	0.362	205.62	74.43
- cross-cutter	4	0.556	205.62	114.32
- chopping trees with a petrol-powered saw and scattering felling residues	4	1.032	205.62	212.20
Total		2.259		475.06
Project variant				
Cutting wood with simultaneous chopping	6	0.095	304.32	28.91

The technical and economic thinning of the considered options are presented in Table 4.

Table 4. Technical and economic indicators

Indicator name	Indicator value	
	Basic variant	Project variant
Type of work	Forest thinning	Forest thinning
Wood species	Larch	Larch
Average volume tree trunk, m ³	0.30-0.36	0.30-0.36
Equipment	Chainsaw MP-5 Ural	Projected chopping without felling wood based on Bobcat T770
Equipment cost, thousand rubles.	9.6	7000
Type of work	Felling Branching Bucking Chopping and spreading felling residues	Cutting wood with simultaneous chopping
Workout for 1 man-day, m ³	5.1	84.5
Annual scope of work, m ³	8873	8873
Labor costs for 1 m ³ , man-h	2.259	0.095
Cost price 1 m ³ , rub.	800.63	249.13
- wage	475.06	28.91
- insurance premiums	28.98	1.76
- equipment maintenance and operation costs	296.59	218.46
Conventional annual cost savings, thousand rubles		4893
Net profit growth, thousand rubles		3792
Payback period of capital investments, years		1.8

Conditional annual cost savings may amount to 4.9 million rubles. Investments for a padless wood chipper based on Bobcat T770 in the amount of 7 million rubles. can pay off in 1.8 years.

The existing equipment for grinding small-sized trees and felling waste is diverse, but none of the devices performs the function of cutting trees. In addition, the delivery of such mechanisms to the work site is difficult (Mikhailov et al., 2018).

6. Findings

The use of a sandless chopper for thinning will reduce environmental damage, reduce the number of accidental visits to healthy plantings, since the base machine is smaller. The machine compresses the soil less. The use of the proposed device eliminates the need to transport cut trees to another place, but will allow them to be processed immediately and fertilize the soil. The clutter of the cutting area and forest warehouses is reduced and their fire hazard is reduced. Labor productivity increases and thinning costs are reduced. Thinning will be less traumatic for the machine operator.

7. Conclusion

Thinning is an important forestry measure, which is aimed at the formation of highly productive, biologically sustainable forest plantations with specified parameters, as well as the preservation and enhancement of their useful functions, the timely use of wood. They are produced by cutting down some of the trees from the plantations and creating favorable conditions for the growth of the remaining best trees of the main species. Thinning is one of the most time consuming and challenging forestry operations. Therefore, the widespread use of thinning is difficult to carry out with a low level of mechanization.

With the right technology chosen, as well as with regular thinning, the following positive results occur:

- Changing the composition of forest stands in a direction desirable for the economy.
- Selection and removal of low-quality wood and conservation of the most valuable species.
- Reduction of the period of growing technically mature wood.
- Improving the quality of the grown timber.
- Increase in total growth per unit area. Increase in the productivity of plantations by 5-15%.
- Improving the sanitary situation in the forest and increasing the resistance of forest stands against harmful factors.
- Strengthening water protection, water regulation, soil protection and other values of the forest.

The machines used in thinning must meet the requirements for productivity and economy, as well as for the implementation of programs with minimal damage to the growing stand and soil.

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