Algorithm for modeling forest transport routes in a forest quarter

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Abstract. The materials of the article relate to the forest industry and can be used in planning the infrastructure of the forest quarter, on the territory of which forest felling will be carried out, combined in time with reforestation operations. This type of reforestation involves replanting coniferous undergrowth that can be damaged during logging operations. In this variant of work, coniferous undergrowth is transplanted from forest areas where felling is planned to nearby forest areas where felling is not planned and coniferous undergrowth is absent. The proposed algorithm for modeling forest transport routes within one forest quarter allows an individual approach to the analysis of each forest area. In addition, it allows you to reduce the cost of performing moving operations both when skidding timber, and when transporting transplanted undergrowth between forest areas.

1. Introduction
The article deals with the technology of combined execution of logging and reforestation works in a forest quarter. This technology provides for the simultaneous cutting of forests [1, 2] and reforestation operations [3] in the forest quarter. The type of reforestation used with this technology provides for the transplantation of coniferous undergrowth, which can be damaged during logging operations. In this variant of work, coniferous undergrowth is transplanted from forest areas where felling is planned to nearby forest areas where felling is not planned and coniferous undergrowth is absent. This option is possible when the outplanting and planting sites are close to each other.

The analysis showed that when using this technology of work, it is possible to increase the efficiency of forest management and to preserve coniferous undergrowth as much as possible in felling areas [4-7]. The currently developed methodology of work in the forest quarter, which provides for the sequential performance of all types of work in the quarter, provides an opportunity to maximally concentrate the volume of logging work and work on replanting undergrowth within it. Rational technology for the development of the infrastructure of the forest quarter will reduce the cost of the integrated implementation of logging and reforestation work on its territory. Special devices have been created for transplanting coniferous undergrowth from under the forest canopy [8-10].

2. Methods and Materials
The purpose of the research: creation of conditions for the transformation of forest quarters (blocks of quarters) into a structural unit of organizational and economic arrangement of the territory with a network of logging roads, skidding trails, technological corridors, timber warehouses for storing timber and temporary storing undergrowth. The study should take into account the entire lease period...
of the forest area and justify the main technological parameters of the infrastructure of forest quarter. The results obtained should make it possible to reduce the movement of equipment, increase the accessibility of cutting areas, increase the productivity of forest machines involved in the implementation of a complex of cutting and reforestation works with replanting coniferous undergrowth from under the forest canopy, and reduce the negative consequences of logging.

The algorithm for choosing a rational technology for work in a forest quarter is shown on figure 1.

The need to transport various goods (timber, coniferous undergrowth) not only towards the boundaries of the forest quarter, but also deep into the forest quarter is a feature of the new technology for performing a complex of works in the forest quarter. The principle of placing points for loading timber and points for temporary storage of undergrowth on the territory of the forest quarter depends on this feature.

The expediency of placing transport routes (main skidding trails and technological corridors) within the forest quarter in such a way that these main and apiary roads meet the following conditions has been revealed:

- It is necessary to ensure the possibility of skidding timber from logging sites to logging roads along the boundaries of the forest quarter and logging roads on its territory. At the same time, it is necessary to ensure the possibility of transporting coniferous undergrowth between forest areas within the forest quarter. The amount of labor and material costs for the creation of loading points, points for temporary storage of undergrowth, the implementation of relocation operations should strive to a minimum;

- It is necessary to ensure the accessibility of all cutting areas on the territory of the forest quarter during all periods of forestry work within its boundaries. At the same time, it should be possible to skid timber and transport coniferous undergrowth in several directions. This is necessary in those years of work in the forest quarter, in which some transport routes created at the previous stages of work in the forest quarter cannot be used to carry out work in the forest;

- It is necessary to ensure the mutually coordinated direction of the main and apiary tracks throughout the forest quarter. These forest tracks should be interchangeable and systematized. The possibility of using main tracks and some apiary tracks should exist in all years of felling on the territory of the forest quarter;

- It is necessary to ensure the possibility of transporting coniferous undergrowth deep into the forest quarter, as well as to any of the sites within its boundaries, so that the unit for transplanting coniferous undergrowth does not have to drive onto the roads that limit the forest quarter;

- It is necessary to ensure the convenience of moving the unit for transplanting coniferous undergrowth between the main skidding trails and sections of the forest quarter located in its various parts;

- It is necessary to provide a rational, from a theoretical, practical and forestry point of view, the distance for transportation of undergrowth between the places of outplanting and planting;

- It is necessary to ensure maximum compliance of the projected network of forest roads with the features of the relief, natural conditions and the location of glades existing in the forest quarter, taking into account the territory of all forest areas that make up the forest quarter.

3. Results and Discussion
The proposed algorithm for modeling timber transport routes is shown in figure 2. It is based on the use of a geographic information system (GIS), including on the spatial characteristics of cutting areas, on volumes stand in their area; information about the presence or absence of coniferous undergrowth, etc. (Block 1).
Figure 1. Algorithm for choosing a rational technology for cutting operations in a forest quarter with replanting of coniferous undergrowth.

The choice of a site for felling is carried out by the researcher by highlighting it on a geoinformation map. The cutting stock of the growing stock and the amount of coniferous undergrowth that needs replanting are determined on the basis of information obtained from the GIS [11]. This takes into account the technological features of the work in the forest quarter, depending on the type of felling. The data on the technology and organization of the work of machines for performing operations on the movement of timber cargo are being studied. A preliminary version of
the placement of technological corridors (Block 2) within the forest quarter, and a variant of the placement of trails for transporting coniferous undergrowth between forest areas is proposed. A variant of the placement of main skid trails for skidding timber from felling sites to logging roads is proposed. The change in the proposed directions of transport routes is carried out when recalculating and comparing various options. The information from block 1 goes to block 2 as a result of the analysis of the values of all characteristics of forest areas required to perform the subsequent steps of the algorithm.

Based on the information received from the GIS, the initial data specified by the researcher, information on the preliminary placement of technological corridors and main skidding trails, the main stages of the calculation are performed: 1) The costs for the transportation of undergrowth between the felling area and the places of its temporary storage (if they are provided for by the work technology) are determined (Blocks 4, 7, 10, 13, 16); 2) The costs for the placement of technological corridors and main skidding trails are determined (Block 12). The filling of these blocks is accompanied by the calculation of the productivity of cutting and reforestation machines used in moving operations.

In this algorithm, the solution of the transport problem on the effective choice of the option for distributing the volumes of transplanted coniferous undergrowth between forest areas is carried out simultaneously with the calculation of the costs of performing work on the transportation of coniferous undergrowth. The purpose of this stage is to find such directions of transportation, the volumes of transported coniferous undergrowth, at which the total costs of moving the entire undergrowth, from all cutting areas in the forest quarter, would be minimal.

In the course of the program, which is based on a similar algorithm for performing calculations, a sequential analysis of all options for laying technological corridors and options for placing main routes is carried out with a gradual minimization of the objective function. The objective function is the total costs of moving coniferous undergrowth and timber, as well as the costs of creating transport routes for transporting coniferous undergrowth and the costs of creating main skidding trails (Block 15). The information obtained as a result of the calculations corresponds to a rational option for the placement of transport routes with a minimum of costs for the implementation of a complex of felling and reforestation work in the forest quarter (Block 14). The result of using the algorithm for modeling transport routes in the forest quarter (Block 17) is the plotting of the required characteristics of technological corridors and main skidding trails on a map characterizing the technology of work in the forest quarter.

4. Conclusion

The proposed algorithm can be the basis for modeling forest transport routes in a forest quarter. Moreover, each forest area must be analyzed individually. Places for the placement of skid trails must be appointed after a thorough inspection of the forest plantations and adjust them taking into account the natural and technological conditions. Particular attention should be paid to the consistency of the transport network, which must one day be designed taking into account the inclusion of all technological elements that may be needed in the next years of work in the forest quarter. In the future, only the improvement of the technological map should be carried out on the basis of its initially created basic version. In connection with the presence in each forest area of an already established or previously formed network of forest roads, forest table lands and glades in the forest quarter, it is not advisable to propose any general scheme of the technology of work on forest areas. The missing part of the working transport and loading network must be outlined in such a way that its elements (technological lines and sites) after the completion of work do not worsen the existing landscape, but become an addition to the existing network of roads and forest table lands.
Figure 2. Algorithm for modeling transport routes in a forest quarter.
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References
[1] Mokhirev A P 2016 The method of selection of forest machines under the climatic conditions. *Forestry Engineering Journal* [Lesotechnicheskiy Journal] vol 6 No 4 (24) pp 208-215

[2] Rukomojnikov K P 2015 Structuring of loading points and main skid road in conditions of existing road network in forest compartment. *Journal of Applied Engineering Science* vol 13 No 3. pp 167-174 DOI: 10.5937/jaes13-8866.

[3] Rukomojnikov K P 2016 Choosing a rational technology and justification of parameters of quarterly development of forest areas [Vybor racional'noj tekhnologii i obosnovanie parametrov pokvartal'nogo osvoeniya lesnyh uchastkov– in Russian] Monograph. (Yoshkar-Ola: Volgatech Publ), p 296

[4] Brissette J C and Chambers J L 1992 Leaf water status and root system water flux of shortleaf pine (Pinus echinata Mill.) seedlings in relation to new root growth after transplanting. *Tree Phys.*, 11 289-303

[5] Brissette J C and Barnett J P 1989 Comparing first-year growth of bare-root and container plantings of shortleaf pine half-sib families ed R A Schroeder, *Proceedings of the 20 So For. Tree Improv Conf.*, 42 354-361

[6] David B I, South D, Paul J, Tom E, Starkey I and Scott A 2012 Planting Deep Increases Early Survival and Growth of Pinus echinata Seedlings *The Open For. Science J.*, 5 33-41

[7] Gwaze D, Melick R, Studyvin C and Hoss G 2006 Survival and growth of container and bareroot shorleaf pine seedlings in Missouri. ed L E Riley *et al Proceedings of the Forest and Conservation Nursery Associations USA: USDA For. Serv. Gen. Tech. Rep. RMRS-P-43*, 123-126

[8] Hadjiyev G M 1999 Substantiation of the parameters of the device for excavating planting material with a root lump. [Obosnovanie parametrov ustrojstva dlya vykopki posadochnogo materiala s prikornevoj glybkoj– in Russian] PhD theses, Russia, Yoshkar-Ola

[9] Lazarev A V 1999 Substantiation of technology and complete set of machines for transplanting of young undergrowth [Obosnovanie tekhnologii i komplekta mashin dlya peresadki podrosta – in Russian]: PhD theses, Russia, Yoshkar-Ola

[10] Rukomojnikov K P 2014 Improving the process equipment for containerized undergrowth replanting [Sovershenstvovanie tehnologicheskogo oborudovaniya dlya peresadki podrosta s zakrytjoj kornevoj sistemoj- in Russian]. Russian Forestry Journal [Lesnoy Zhurnal]. No 2 (338) pp 9-17

[11] Mokhirev A P and Egarmin P A 2011 Geographic information system of planning of forest resources optimal development Systems. Methods. Technologies. No 4 (12) pp 172-176