The Algorithm for Evaluating Availability of Wood Resources Considering Ecological, Technological, Technical, Transport and Economic Restrictions

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Abstract. The article substantiates the relevance of the algorithm development for assessing the availability of wood resources. The actual conditions of the Russian timber industry complex are considered. The authors propose an algorithm with regard to the various aspects of this issue and possible restrictions. It includes a consistent assessment of the environmental, technological, technical, transport and economic availability of wood at a particular site. Prospects of application of the developed algorithm are defined.

1. Introduction

One of the system problems of the timber industry complex is the lack of accuracy in assessing its resource potential. It's defined in the strategy of development of the forest complex of Russia. The main factors of this problem are: insufficient accuracy of forest resources accounting, low technical level of forestry works and poorly developed infrastructure in forests (Karakchieva & Chumachenko, 2016, Knyazeva, 2005, Chung, 2008). In this regard there is a necessity in a certain unified algorithm. It should allow make an accurate assessment of wood resources based on their qualitative and quantitative characteristics and geographical location. This algorithm should be applicable at the level of logging enterprise, region and state. The development of an algorithm for assessing the availability of wood resources is the purpose of the author's research.

At present, it is difficult to imagine a large forest industry company with no database of geographic information systems (GIS). Such a database must contain a data set on the leased area. GIS allows analyzing a wide range of information. Different variants of logging are modeled on the basis of the data obtained. Effective planning allows reducing the cost of logging and transportation. All this leads to reduction of wood in cost.

Efficient use of data also contributes to optimal planning of the most profitable wood transportation routes. Planning is carried out considering the season, the choice of warehouse location and development technologies of forest areas.
2. Material and methods
The objects of research were the algorithm for evaluating the availability of wood resources considering ecological, technological, technical, transport and economic restrictions and Gremychiy logging area of JSC “Novoyeniseisky Wood-Chemical Complex” of the Krasnoyarsk Territory. The main methods used were analysis, statistical and mathematical planning, modeling, standard methods of conducting experiments and assessing the availability of wood resources, etc., which may be used in other developments.

3. Results
The term "availability of wood resources" was initially equated to the economic efficiency of the development of the forest area (or the value of forest rent) (Romanov, 2006, Sokolov et al., 2016, Tret’yakov, 2015). However, in given study is determined that this term has a broader meaning. Such statement of the question finds only partially reflection in the modern literature (Efremov, 2009, Mayorov, 2014, Tret’yakov, 2015). The overall assessment of the availability of wood resources consists of successive assessments of five components. These components are environmental, technological, technical, transport and economic accessibility.

The authors developed an algorithm for assessing the availability of wood resources in a certain area (see Fig. 1). The research is based on previously obtained theoretical and methodological elaborations (Mokhirev et al., 2018, Mokhirev et al., 2018, Pozdnyakova & Mokhirev, 2018).

According to the algorithm, at the first stage the environmental availability of the site is estimated. This is due to legislative restrictions on the use of forest resources. They can not be cancelled or modified for the production needs of the logger. Environmental accessibility is expressed in a legislative prohibition on the use of certain wood resources. Some forest areas perform important ecological functions and have high ecological value. Therefore, these restrictions serve to protect natural processes from logging. The formula of ecological accessibility of wood has the form (1):

\[ EcW \notin L_{lp}, \]

where \( EcW \) – ecologically available wood;
\( L_{lp} \) – legally prohibited felling of wood.

Based on this, wood resources can be recognized as:

1) unavailable (they belong to the category of specially protected) or temporarily unavailable (for example, areas where reforestation takes place). These types of resources are not suitable for industrial development. They are not included in the further assessment;

2) partially available (suitable for partial felling) and available (suitable for complete deforestation). These resources are further assessed for technological accessibility.

Technological availability of wood resources is an opportunity to develop certain wood resources by a certain technology at a certain moment of time. Using a different technology may lead to the unavailability of these resources. In addition, this type of availability refers to a certain type of harvested wood products. For example, harvesting technique of round timber makes unavailable getting chips. Thus, on the basis of technological availability wood resources are divided into:

1) unavailable (applied technology doesn’t allow make logging in existing ecological and natural-climatic conditions. For example, the solid felling technology cannot be used in selective felling sites; technology of logging on the plains becomes not suitable when cutting of mountain forests;

2) available (logging technology correspond to all standards for this site). It should be noted that the site can move to this category from the unavailable one, for example, if the logging team strained and master the technique. Also, the logger must obtain an admission to this type of works.
Determination of ecological availability of wood resources

Assessment of forest protection categories:

\[ \text{EcW} \not\in \text{Llp} \]

where \( \text{EcW} \) – ecologically available wood;

\( \text{Llp} \) – legally prohibited felling of wood

Determination of technological availability of wood resources

1. Harvesting technology
2. Type of felling
3. Average volume and diameter of trees
4. Harvesting season

Compliance of technical characteristics of the applied machines system to the specified natural-climatic conditions

\[ \frac{t_{\text{max}}}{d_{\text{max}}} \geq \frac{t_{\text{ter}}}{d_{\text{mash}}}; \quad \delta_{\text{mash}} < \delta_{\text{soil}}; \]

\[ \frac{t_{\text{max}}}{d_{\text{max}}} \geq d_{\text{max}}; \quad t_{\text{max}} \leq T_{\text{env}}; \quad t_{\text{max}} = T_{\text{term}}. \]

where \( t_{\text{max}} \) – maximum working slope of the machine; \( t_{\text{ter}} \) – the maximum slope of the terrain; \( d_{\text{mash}} \) – specific ground pressure; \( \delta_{\text{soil}} \) – soil bearing capacity; \( d_{\text{max}} \) – maximum diameter of trees processed by the working body; \( d_{\text{max}} \) – maximum diameter of trees; \( t_{\text{max}} \) – operating temperature range of the machine; \( T_{\text{env}} \) – temperature range of the environment.

Determination of transport accessibility of wood resources

1. Development of forest infrastructure (length of road network)
2. Technical condition of roads
3. Type of harvested wood transportation
4. Average distance of timber removal
5. Remoteness of plantations from existing roads

Availability of routes corresponding to transport equipment

Transport unavailable resources
Transport available resources

Determination of economic availability of wood resources

1. Selling price of wood
2. Productive resources price
3. Type of products
4. Species composition
5. Remoteness of forest reserve per 1 ha

Profitability of products: \( \text{EA} = I - C_{\text{lg}} - C_{\text{transp}} - C_{\text{infr}} - R \),

where \( \text{EA} \) – economic availability of forest resources; \( I \) – income from selling the timber products; \( C_{\text{lg}} \) – logging costs; \( C_{\text{transp}} \) – costs of timber products transportation; \( C_{\text{infr}} \) – costs of creation and maintenance of the necessary transport infrastructure; \( R \) – rate of production profitability.

Figure 1. The algorithm for assessing the availability of wood resources.
Further, technologically available wood resources are assessed in terms of technical availability. Technical availability of wood resources is an opportunity to master wood resources by a certain technique at a certain moment of time. Technique with certain characteristics correspond to certain natural and production conditions. The formula of technical availability of wood has the form (2):

\[
TA = \begin{cases} 
    i_{max} \geq i_{terr} , \\
    \delta_{mash} < \delta_{soil} , \\
    d_{w,b} \geq d_{max} , \\
    t_{max} \geq T_{max} , \\
    t_{min} \leq T_{min} .
\end{cases}
\]  

(2)

where \( i_{max} \) – maximum working slope of the machine;  
\( i_{terr} \) – the maximum slope of the terrain;  
\( \delta_{mash} \) – specific ground pressure;  
\( \delta_{soil} \) – soil bearing capacity;  
\( d_{w,b} \) – maximum diameter of trees processed by the working body;  
\( d_{max} \) – maximum diameter of trees;  
\( t_{min}, t_{max} \) – operating temperature range of the machine;  
\( T_{min}, T_{max} \) – temperature range of the environment.

Technical availability assessment allows to divide resources into the following categories:

1) unavailable (the system of machines used by the logger does not correspond the natural and production requirements of the site);

2) available (the system of machines enables harvesting of wood resources in the required technology). Wood resources in this category are further assessed based on transport accessibility.

Transport availability of wood resources is the ability to transport them to the point of delivery by certain technical means at a certain time. It should be noted an important fact. Wood resources can become available for transportation with the change of the transportation conditions (modernization of machines, changing routes, etc.). This type of accessibility is closely related to the technological and technical accessibility of wood. Wood resources on the site can be:

1) not available for transportation. This situation is possible because of the various reasons: geographical, technical, technological, environmental. Their nature consists in the key fact that the distance between points of removal and delivery of wood is more than the maximum admissible distance of timber removal. This distance is characterized by obtaining standard profit from the harvested products (Ghafarrian & Sobhani, 2007, Mokhirev & Bolotov, 2010, Tret’jakov, 2015, Trishkin et al., 2017).

2) available for transportation. In this case the shipping costs do not exceed the standard values. Costs depend on the development of transport networks (both land and water) and the technical equipment of the logger.

The next aspect of the analysis within the proposed algorithm is an economic accessibility. At the same time, technological, technical and transport accessibility of wood can be combined and classified as economic accessibility. This can be explained by the fact that the change in the size of financial investments affects the system of forest machines, technology of wood harvesting, transport infrastructure is created, etc. Thus, investment solves the problem of transport, technological and technical inaccessibility of forests.

Economic availability of wood resource is an opportunity to obtain the necessary level of profitability of logging products. It is determined by the ratio of the market price of logging products and its full cost (including logging and transportation to the consumer). The formula of economic accessibility is as follows (3):

\[
EA = I - C_{lg} - C_{transp} - C_{infr} - R,
\]  

(3)

Where \( EA \) – economic availability of forest resources;  
\( I \) – income from selling the timber products;
\( C_{\text{lg}} \) – logging costs; 
\( C_{\text{transp}} \) – costs of timber products transportation; 
\( C_{\text{infr}} \) – costs of creation and maintenance of the necessary transport infrastructure; 
\( R \) – rate of production profitability.

Thus, the assessment of wood resources based on economic availability allows allocating:

1) economically unavailable resources. The profit ability of this forest area development is below the desired level. The current level of material-technical and personnel support of the logger does not allow mastering this site economically effectively.

2) economically available wood resources. Industrial development of the analyzed area of the forest fund should provide the logger with the necessary level of profit ability of the final product. In this case the efficiency is achieved with a given set of parameters. They also define the final product. It can be both round wood and production of deep timber processing, for example, wood boards. Thus, the term "availability of wood resources" can be defined the most accurate as follows: the possibility of environmentally safe and cost-effective harvesting of a certain type of wood products using certain equipment and technology.

After the market had been studied for software products, designed for the work with geographic information, the desktop products group “ArcGISforDesktop” (ArcGIS) was selected. It was developed by “ESRI” specialists. ArcGIS has a large toolkit for processing geographic information, storing it, providing it to a user in various forms, as well as for the in-depth analysis and modeling of various situations.

The creation of GIS database begins with the selection and digitization of the initial data (the boundaries of the area of interest, transport routes, hydrography, terrain data, etc.), necessary for the analysis. Spatial data is stored in the GIS as vector and raster layers and as tabular data.

Based on the transport paths in the Network Analyst module, a network - Network Dataset is made in the form of a graph. When using graph theory, the network offers the following opportunities:

- analysis of the most optimal ways of removal;
- determination of removal seasons;
- determination of optimal sites for the location of warehouses;
- determination of the necessity for new transport routes, etc.

4. Discussion

The writing team plans to publish the developed method for determining the availability of wood resources on a web server for the ease of use by the end user. However, before then, all algorithms and models are to be tested to verify their correct operation. When using algorithms and models of geostatic analysis by accessing a web server, the user will be able to open a web application. In the web application window a substrate of satellite images with the infrastructure superimposed is projected. The user adds the required data on the map and receives the result of the loaded graph analysis in the form of optimal routes for the transportation of raw wood materials.

The lease area of the Gremychiy logging area (LA) of JSC “Novoyeniseisky Wood-Chemical Complex” was chosen as an experimental platform for testing the proposed GIS. This territory is characterized by a large number of transport routes of various kinds. Natural and geographical conditions of the territory are also different. This makes it interesting for logging modeling.

The removal of sawlogs is carried out on two main roads: 110 kilometers in length (including 101 kilometers for the all-year-round operation) and 160 kilometers (including 125 kilometers for the all-year-round operation), respectively.

Based on a preliminary analysis of the timber base of Gremychiy LA, the optimal scope of possible annual wood removal was determined. It makes 340000 m³. With the existing output coefficients of sawing raw materials, LA will annually supply 220000 m³ of sawing raw materials for the driving. This scope will help to stabilize the supply of extracted raw materials during the entire planned period.
Using the provided methods for determining the availability of wood resources and the developed GIS, the authors defined the accessible and inaccessible forest areas of the Gremychiy LA. The results showed that 51% of the rental base of the Gremychiy LA is considered available for development (See Fig. 2). Figure uses a color marking: green color - wood resources are available, red color means they are not available.

![Figure 2. Final map of Gremychiy LA with wood accessibility assessment.](image)

5. Conclusion
The developed algorithm can be used as a basic tool for assessing the availability of wood resources. Its application is possible at the level of the enterprise, region and country (with appropriate adjustments). Using of this algorithm makes it possible to identify areas of forest fund available for industrial development, to choose the optimal system of machines and to build the most efficient technological process of timber harvesting. It becomes possible thanks to the use of environmental, technological, technical, transport and economic constraints.

The proposed methods can be used:
1. At the strategic level of making managerial decision:
   - development of forest road infrastructure;
   - tracking the potential of business and fuel, fire wood, etc.
2. At the tactical level of decision making:
   - gradation of development of cutting areas;
   - choice of technology for the development of the forest area;
   - selection of the logistic chain of wood delivery to the consumer, etc.
3. At the operational level of decision making:
   - choice of the best routes for log trucks;
   - drawing up work plans for felling complexes, etc.

As can be seen from the above, this method is the best tool for integration into the logging company’s control. Using it can be beneficial at all control levels. At the end of the day, its use significantly increases the performance of a company.

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