A model for improving the efficiency of forest industry enterprises in the context of rational environmental management

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Abstract. The development of the forest industry is one of the important goals of state policy. The purpose of the work was to study certain aspects of the efficiency of Russian forest industry enterprises in the context of rational environmental management and to develop a graphical model for its improvement. The main research methods are analytical, modeling, and statistical data processing. As a result, information was obtained on the current level of efficiency of production of forest industry key products by regions of the country. The development of the model was based on the general hypothesis of the study, that expanding the depth of wood biomass processing while reducing the negative impact on the environment leads to increased efficiency and sustainable development of enterprises in the forest industry. The proposed model demonstrates certain aspects of the interaction of forest industry enterprises with the environment. The most important elements of this model are waste-free production and the deep processing production, based, among other things, on the use of waste from the main production. To increase the efficiency of forest industry enterprises, it is extremely important to develop and implement environmental management measures.

1 Introduction

Rational environmental management is one of the key elements in the state regulation of industry, as well as one of society requirements in modern conditions [1-3]. A significant part of the world community, adopting the principles of sustainable development, takes care of the natural environment. At the same time, it is recognized that industry and production activities are integral components of any state [4]. At the same time, business activities are not possible without certain restrictions. In terms of interaction with the environment and the withdrawal of certain natural resources, such restrictions should be reduced to the following postulates [5-8]:
- minimal possible harm to the natural environment – minimum emissions, discharges, waste, noise, etc.;
- maximum possible use of the entire volume of available natural resources;
- restoration of renewable natural resources;

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- reclamation of lands and other natural objects;
- protection of rare animals, plants, and natural monuments.

Rational environmental management involves the use of natural resources, considering minimizing the impact on nature while maximizing economic effects. The state policy pursued in Russia is designed to stimulate such a business approach to perform the main functions of protecting the rights and interests of citizens. At the same time, which is quite natural, the conditions for rational use of natural resources in different industries differ significantly. Industries using renewable natural resources have the greatest potential in this area. These primarily include biological resources. For this reason, agriculture, fishing industry and timber processing complex are the most interesting for research and development, followed by the implementation of various programs to improve the efficiency and rationality of environmental management. In this paper, the object of research is the forestry industry, which is due to significant changes taking place in it against the background of restrictions from a number of foreign countries.

The main goal of any business is to maximize profits. In practice, this is realized through maximizing the effectiveness of various aspects of the company's work. At the same time, the activity of any production organization includes many processes occurring both within the business structure and in its interaction with the external environment. Thus, we can say that the goal of an industrial enterprise is to increase efficiency as a result of optimizing a variety of processes.

It should be said that certain aspects of increasing the efficiency of timber enterprises, including in the context of rational environmental management, have been studied by various authors [9-11]. At the same time, key hypotheses and research results are often focused on maximizing profits, leaving social and environmental aspects aside. On the contrary, in case of focusing the attention of researchers on environmental and other issues, the profit and efficiency of the enterprise become less critically important aspects, which is also incorrect. Undoubtedly, the integration of such different tasks into a single topic and finding optimal solutions in this subject area is extremely difficult. According to the author, various modeling methods can and should be one of the tools in this direction.

This work is devoted to the study of certain aspects of the efficiency of enterprises of the Russian forest industry and the development of a graphical model for its improvement.

2 Materials and Methods

The purpose of this work is to study certain aspects of the efficiency of Russian forest industry enterprises in the context of rational environmental management and to develop a graphical model for its improvement.

The paper is based on the works of well-known authors in the field of improving the efficiency of enterprises in the forest industry, rational environmental management, as well as the use of individual modeling tools to solve timber industry problems. The research uses methods – analytical, modeling, statistical data processing. In the course of the work, publicly available software products were used – Microsoft Office Excel and Statistica. This should facilitate the replication of the results and their reproducibility. Publicly available data from the Russian EMISS system (Unified Interdepartmental Information and Statistical System) were used for statistical processing.
3 Results and Discussion

The first stage of the study was the analysis of the current situation regarding the efficiency of the Russian forest industry enterprises. To do this, statistics were analyzed in terms of individual indicators for the period 2015-2022. According to the author's opinion, the most representative information is about the profitability of products produced at domestic enterprises. At the same time, it should be noted that Russian regions differ significantly both in terms of capabilities and in terms of the level of forest industry development. This has led to additional interest in a detailed analysis of performance differences by region. In this case, the team of authors continued the research carried out over a long period of time [12]. Regional differences are explained both by the historical peculiarities of the forest industry development in the regions and by natural and climatic factors. It is quite logical that the regions have different reserves of wood resources both in quantity and quality. It is also important to understand that the western regions of the country, traditionally located close to more attractive markets, have significantly reduced their economic efficiency indicators under the conditions of sanctions restrictions.

Profitability can be considered one of the key indicators characterizing the economic efficiency of enterprises. At the same time, if we focus on this indicator in relation to specific types of products, it gives a wider range of information [13-15]. This is due to the fact that different types of goods in the industry are produced with varying degrees of environmental stress (Table 1) [16-18].

Table 1. The degree of environmental stress from certain types of production in the forestry industry.

<table>
<thead>
<tr>
<th>Type of production</th>
<th>Degree of load</th>
<th>Characteristic</th>
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<tbody>
<tr>
<td>Logging</td>
<td>Moderate-high</td>
<td>The main impacts are the wood removal (deforestation), soil disturbance, atmospheric pollution from transport and logging equipment emissions. When compensating for deforestation by reforestation, this production should be attributed to the least environmental impact.</td>
</tr>
<tr>
<td>Mechanical processing (sawing and planing of wood)</td>
<td>Medium</td>
<td>The main impacts are waste generation, emissions from drying lumber, energy consumption during equipment operation. Waste generated in most large enterprises is used to produce additional products.</td>
</tr>
<tr>
<td>Furniture production</td>
<td>Medium</td>
<td>Insignificant amounts of waste. Nevertheless, harmful adhesives, varnishes and other chemicals are often used in production, which does not allow to classify production as minimally affecting nature.</td>
</tr>
<tr>
<td>Slab production (fiberboard, chipboard, plywood, etc.)</td>
<td>High</td>
<td>Main impacts: large amounts of emissions, waste and discharges. These are water-, material- and energy-intensive industries. Only a part of the waste received is recyclable. These areas relate to the deep processing of wood and cause the greatest harm to the environment.</td>
</tr>
<tr>
<td>Timber chemical production</td>
<td>High</td>
<td></td>
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<tr>
<td>Pulp and paper production</td>
<td>High</td>
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The study analyzed the efficiency (profitability) of these types of production. The most interesting for practical evaluation are the various production characteristics – sawing and planing of wood and slab production (production of veneer, plywood, wooden slabs and panels).

Given that more recent data are the most representative, let's give an example with the results obtained for 2021 and 2022 (complete data for 2023 were not available at the time.
of writing this paper). On average, the profitability of sawing and planing wood in 2022 was 3.83%, and the production of veneer, plywood, wooden slabs and panels was 14.09%. At the same time, there was a significant decrease compared to 2021, when this figure for both industries was more than 35%. The distribution of profitability indicators by regions of the country is more clearly shown in Figures 1 and 2.

![Fig. 1. Concentration chart for the indicator "Profitability of sawing and planing wood" by regions of Russia in 2022.](image1)

![Fig. 2. Concentration chart for the indicator "Profitability in the production of veneer, plywood, wooden slabs and panels" by regions of Russia in 2022.](image2)

It is clearly seen from the presented diagrams that the mechanical processing of wood (Fig. 1) is significantly inferior in the economic efficiency of deep processing. Similar results were obtained for other types of activities and products of the forest industry. This suggests that with due attention to environmental issues, namely the use of highly efficient environmental protection equipment (treatment plants), deeper processing should allow achieving high economic results with reduced impact on nature.

Thus, the main focus of modeling in this study should be aimed at the implementation of the following hypothesis: the development of the depth of wood biomass processing
while reducing the negative impact on the environment leads to increased efficiency and sustainable development of enterprises in the forest industry.

Analyzing the results obtained, as well as the work of various authors, the practice of domestic and foreign enterprises, a graphical model was formed to increase the efficiency of forest industry enterprises in conditions of rational environmental management (Fig. 3). The presented blocks in the model characterize various aspects of the activities of enterprises that contribute to achieving the goals set. The key objects in this case are the timber industry and the environment. There is a complex of interactions between them, the main of which are the transfer of resources from the environment to the enterprise and a complex of negative impacts directed in the opposite order.

![Graphical Model](image)

**Fig. 3.** A model for improving the efficiency of forest industry enterprises in the context of rational environmental management.

It is important to note that the wood waste generated during the production process in the presented model does not enter the natural environment. They are used to obtain additional products. Thus, there is a cycling of production and the implementation of waste-free production.

Another important element of this model is the obtaining products of n-degrees of processing. Considering that enterprises receive wood waste, and their use is an essential condition, production cannot be limited to the mechanical processing of wood raw materials (obtaining lumber). In practice, certainly, most enterprises will not be able to organize additional production at their industrial sites. This is due to the narrow specialization, limitations of the financial plan and other factors. In these conditions, the logical way out is to transfer waste to large industrial enterprises that traditionally lack raw materials. The processing degree may include several stages, ranging from mechanical to deep (while deep processing is often associated with the reuse of waste generated).

The mechanism of wood waste transfer and the interaction of various business structures is a separate important aspect that allows this model to be implemented. It, like many other processes, is regulated by a set of elements presented in the upper part of the model:
1. Technological modernization is the basis for improving the efficiency of enterprises in the forest industry. Traditionally, the industry is characterized by high wear and tear of equipment and machinery. Also, the Russian forestry industry is significantly inferior to foreign competitors in the speed of implementation of advanced technological developments. At the same time, without such modernization, there is no need to talk about leadership, efficiency and competitiveness in the global market.

2. Organizational and economic transformations are the other side of the necessary changes. In addition to technology, changes are needed in approaches to management, many economic processes, the organization of work and processes in production. Without qualified management and business economy management, it is also impossible to achieve high economic efficiency.

3. Environmental influences. This is a complex of influences of various institutions and factors that determine the enterprise policy and various elements in the behavior of timber enterprises. The state, competitors, geopolitical situation, natural and climatic factors and much more - they form the limitations and directions in which enterprises of the forest industry should develop. Ultimately, it is the external environment that determines the need for rational environmental management for enterprises in Russia.

4. Environmental management measures are allocated in a separate block, since it is on them the effectiveness of the use of natural resources, economic efficiency, as well as compliance with the environmental and partly social agenda depend. The impact of such events is difficult to overestimate. They may relate to various aspects of the activities of enterprises, but their goal is the same – to increase the efficiency of the enterprise while observing a number of existing restrictions.

The presented model, in the author's opinion, reflects the requirements of modern society and the state's view on the industry development.

4 Conclusion

As a result of the conducted research, a graphical model of increasing the efficiency of forest industry enterprises in conditions of rational nature management was obtained. It clearly demonstrates certain aspects of the interaction of forest industry enterprises with the environment. The most important elements of this model are waste-free production and the deep processing production, based, among other things, on the use of waste from the main production. To achieve these goals, significant technical, organizational and economic transformations aimed at the development of rational environmental management are also necessary. At the same time, all the activities of the enterprise and these events take place under the influence of a complex of environmental factors.

The further work of the team of authors is connected with the continuation of the research and detailing of the resulting model. In particular, special attention should be paid to measures for the development of rational environmental management. Research is expected in terms of technological modernization and organizational and economic transformations.

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