

Reducing the environmental impact of forestry enterprises

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Abstract. The paper focuses on examining the environmental impact of forest industry enterprises and developing measures to mitigate it. The authors identify humans as the primary factor influencing the environment in the modern world, with forests serving as a crucial tool for reducing anthropogenic effects. Under such conditions, the activities of forest industry enterprises must be subjected to strict control and analysis, as they represent one of the most significant contributors to deforestation. The research highlights key activities within the industry and identifies the most substantial and critical environmental impacts associated with major processes (types of production). Based on consultations with experts (representatives of large forest industry enterprises) and the conducted study, a list of measures aimed at reducing negative environmental impacts has been developed. The main conclusion emphasizes that increasing attention to sustainable development should be regarded as a fundamental basis for any transformations within the industry aimed at normalizing interactions with the environment.

1 Introduction

The state of the environment is one of the most critical issues in the development of modern civilization [1]. General pollution, the accumulation of vast amounts of waste, the extinction of wildlife species, and global warming are interconnected elements in a long chain of various aspects of ongoing global changes [2]. The source of these transformations is human activity. Anthropogenic impact exerts the greatest influence on environmental changes, with industrial activities and their specific outcomes being the primary contributors [3].

One of the key trends in recent decades in both science and practice has been the focus on carbon footprints and decarbonization [4,5]. Minimizing carbon emissions, capturing carbon, and offsetting its impact through the creation or implementation of carbon units are among the most significant topics in scientific research by various authors. In addition to theoretical developments, numerous projects in this area are being implemented by different nations [6]. Decarbonization of the economy is especially relevant in European countries, influencing regulatory frameworks for business activities, particularly industrial enterprises. Achieving carbon neutrality is a prominent goal declared at the highest levels.

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In practice, attaining this state requires radical transformations in the production processes of numerous industrial structures. Nevertheless, the overall efforts and actions in this direction are commendable.

In Russia, as in other countries such as Brazil, Canada, Finland, China, and others, forests serve not only conservation and protective functions but also fulfill production-economic roles. Their key resource (wood) is used to produce a wide range of products [7]. The forestry industry consumes vast amounts of timber (approximately 113 million cubic meters were harvested in Russia in 2023). However, beyond logging activities, this sector also contributes to negative environmental impacts. It must be noted that forestry remains an industry with all its associated consequences [8]. At the same time, enterprises contribute positively through afforestation (reforestation) efforts and addressing other environmental issues via various comprehensive programs. This study will examine specific aspects of the environmental impact caused by forestry enterprises.

2 Materials and methods

The objective of this study is to investigate the specific impacts of forestry enterprises on the environment and develop measures to modernize their activities to minimize negative effects. To achieve this goal, the following tasks were planned: examining and assessing key production processes in forestry enterprises; identifying major areas of environmental impact associated with individual production processes; devising strategies to reduce environmental impact; and systematizing information on minimizing environmental impact based on the identified processes.

The research is based on scientific findings from both Russian and international authors, as well as previous works of the research team. To evaluate the processes in forestry enterprises, experts from leading industrial organizations in this sector were engaged. Their expert opinions enabled an assessment of the actual practices employed by forestry enterprises and provided insights into existing challenges concerning their interaction with the environment. Classical research methods such as analysis, synthesis, and generalization were utilized. Additionally, the Microsoft Office Project software suite was employed to detail forestry enterprise processes and identify areas of environmental impact.

3 Results and discussion

The conducted study revealed that the forest industry is characterized by a significantly differentiated structure. Enterprises within this sector vary in terms of their activities, applied technologies, resources, products, and other factors. Production volumes also differ substantially. The following key areas associated with the forest industry were identified:

- Logging the primary purpose of which is to establish the raw material base for the entire forest industry.
- Forestry which has an indirect impact on the forest industry. Its main tasks include studying forests, protecting them from fires, pests, and diseases, and restoring them. Nevertheless, it should be acknowledged that sustainable development of the sector is impossible without this area.
- Mechanical wood processing where the enterprises are concentrated on industrial sites and produce wood products without chemically transforming the raw material. Products include lumber, plywood, carpentry items, houses, etc.

- Forest chemistry where the enterprises use various chemical substances and reactions to produce goods that are structurally different from the original raw material. Examples include rosin, alcohols, essential oils, paints, and more.
- Pulp and paper production which involves the manufacture of pulp, paper, cardboard, and their various modifications.

It is important to note that the last two areas pertain to deep wood processing. From an economic perspective, these are the most profitable areas and are prioritized for development by the government [10]. However, they are also the most hazardous and harmful to the environment due to the use of various chemicals in production processes. Additionally, it should be noted that some classifications of the forest industry exclude the first two elements from this structure. According to this perspective, a comprehensive approach to understanding and assessing the impact of the forest industry requires consideration of all interactions with forest (wood) resources.

Given such a complex and fragmented structure, individual production processes were generalized within the study to determine their specific environmental impacts. Selected results are presented in Table 1.

Table 1. Directions of impact of key processes of forest industry enterprises on the environment.

Process/production	Direction of impact
Timber harvesting	Decreased biodiversity; generation of huge amounts of waste (branches, twigs, stumps, green wood, etc.); impact on climate change (reduced CO2 absorption, opportunities to regulate climate change); impact on water resources (water quality, condition of river bodies, water balance, etc.); soil erosion; emissions of CO2 and other substances from logging equipment.
Transportation of timber from forest areas and products to the consumer	Emissions of harmful substances into the atmosphere (primarily CO2); release of fuels and lubricants (during operation of various equipment) into the environment; pollution of rivers during timber rafting (wood and various fuels and lubricants); noise pollution, etc.
Mechanical processing of wood	Generation of wood waste (bark, slabwood, chips, shavings, sawdust, wood dust, etc.); pollution (emissions, waste, fuels and lubricants, etc.) from operation of equipment; water pollution (during its use in technological processes), including various chemicals; energy use (often based on fossil fuels, which leads to greenhouse gas emissions); noise pollution, etc.
Production of board products (fiberboard, chipboard, OSB, etc.)	Pollution (emissions, waste, fuel and lubricants, etc.) from the operation of machinery and equipment; water pollution (these are water-intensive industries), including various chemicals; energy use (often based on the use of fossil fuels, which leads to greenhouse gas emissions); noise pollution, etc.
Forest chemical production	Emissions of hazardous substances into the atmosphere (sulfur, nitrogen, organic compounds, carbon oxides, etc.); water pollution (including heavy metals, organic compounds, etc.); waste generation (difficult to use for other purposes - for example, lignin); environmental pollution from the operation of machinery and equipment; the use of large amounts of energy (and a range of related problems), etc.
Pulp and paper production	Water pollution (including chlorides, phenols, sulfides, etc.); air pollution (sulfur, nitrogen, organic compounds, carbon oxides, etc.); formation of a significant volume of wood waste; consumption of large amounts of energy (using fossil fuels to generate it increases the formation of greenhouse gases), etc.

The directions of influence encompass the primary, generalized methods of impact associated with the specified industries and processes. In practice, each enterprise and production facility exert a wide variety of influences, which are determined, among other factors, by the specific characteristics and scale of production. A direct assessment of all types of impacts from an enterprise (or individual workshop/process) may be included in the environmental documentation titled "Environmental Impact Assessment." Additionally, the specific features of such impacts are established through the conduct of environmental expertise. It is important to note that Table 1 presents generalized processes and productions due to their vast number at each enterprise within the sector. At the same time, this work also involved a detailed examination of the main processes at each type of enterprise under study. A fragment of the database formed during the research is presented in Figure 1.

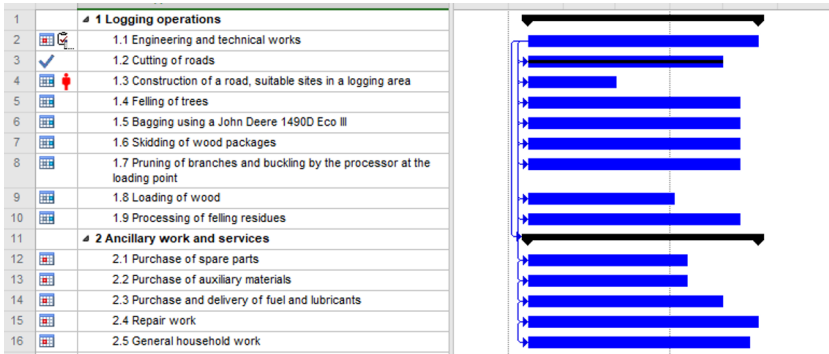


Fig. 1. A fragment of a Gantt chart of logging operations at a forest industry enterprise in Microsoft Office Project.

The obtained results indicate differentiated types of environmental impacts caused by forestry enterprises. The primary impacts include the generation of various wood wastes, the emission of carbon dioxide and other gases (converted to CO₂ equivalents), the production of polluted wastewater, and the disruption of natural ecosystems during logging and associated activities.

Based on these findings, a list of measures was developed to reduce the environmental impact of forestry enterprises. Considering that the forestry industry involves the use of forests and timber, and given the similarity of many impacts, these measures are presented as a general list without sector-specific distinctions:

1. Modernization of industry enterprises to reduce waste generation.
2. Implementation of closed technological cycles and recycling.
3. Installation of advanced purification equipment.
4. Expansion of production facilities utilizing secondary wood resources (including the production of goods and semi-finished products within forest areas).
5. Reduction in energy consumption and transition to cleaner energy sources (the most realistic option being hydroelectric power).
6. Expansion of certification and standardization processes.
7. Development of training and professional development systems for personnel.
8. Sustainable forest management.
9. Use of environmentally friendly materials (e.g., coatings, adhesives, resins).
10. Strengthened monitoring measures for forest territories.
11. Increased attention to sustainable development issues.

These measures will significantly optimize the operations of forestry enterprises and, in particular, reduce their environmental impact. It is worth noting that modern forestry, like many other industries, emphasizes reducing its carbon footprint [11]. According to the authors, this aspect, along with others discussed above, can be viewed as individual components of policies aimed at sustainable development. Such policies can and should serve as a strategic foundation for industry development and modernization.

It is essential to understand that forests are a national asset, and their use entails a range of complexities. Nevertheless, both now and in the foreseeable future, forests and their resources will continue to be utilized for producing various valuable products. In this context, minimizing the environmental impact of forestry enterprises becomes a critical task. Its resolution depends on collaboration among businesses, governments, and society. Only through joint efforts can we preserve a high-quality environment for future generations.

4 Conclusion

The study identified the key environmental impacts of enterprises in the forestry industry. The forestry sector represents a highly differentiated structure, encompassing enterprises that are complex and distinct in various aspects of their activities. Nevertheless, nearly all these enterprises are unified by their reliance on wood and forest resources for the production of diverse goods. It is noteworthy that the efficiency of forest resource utilization in Russia lags behind that of several major forestry nations worldwide. However, the observed positive developments have had a favorable influence on both the economic and environmental dimensions of the industry's operations.

During the research, information was systematized regarding the most significant environmental impacts associated with specific processes (or productions). It was established that the primary impacts include: the generation of various wood waste products, emissions of carbon dioxide and other gases (converted to CO₂-equivalent), polluted wastewater discharges, and disruptions to natural ecosystems during logging and related operations. Based on the obtained data, a set of measures was proposed to mitigate the adverse environmental effects caused by forestry enterprises.

A critical and systemic measure should involve increasing attention to sustainable development. This approach would serve as a foundation for implementing diverse programs aimed at both forest conservation and improving the production processes within enterprises.

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