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Strategic Assessment of the Impact of Forestry on the Environment to Achieve Sustainable Development

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ABSTRACT

The relevance of the proposed topic is driven by global climate change and the urgent need to optimize the management of natural resources. Forests play a central role in the global carbon balance and are of great socio-economic importance for local communities. The research *aims* to analyze forest management strategies and their environmental impacts. The study focuses on forest ecosystems in different regions and climatic zones. The *methodology* is based on a comprehensive analysis of scientific literature, statistical data, and the examination of practical examples. The article *highlights* the dynamics of forest ecosystem restoration following different types of forestry interventions in different climatic zones, including the Ukrainian context. The impact of forest management on global carbon balances and the socio-economic sphere is assessed. The research shows that adaptive strategies can contribute to sustainable development and biodiversity conservation. The *conclusions* provide recommendations for the implementation of these strategies at the national level, especially in Ukraine.

KEYWORDS: Biodiversity, carbon balances, forestry, socio-economic impact, strategic assessment, sustainable development.

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Evaluación estratégica del impacto de la silvicultura en el medio ambiente para lograr el desarrollo sostenible

RESUMEN

La relevancia del tema propuesto está impulsada por el cambio climático global y la urgente necesidad de optimizar la gestión de los recursos naturales. Los bosques desempeñan un papel central en el equilibrio global de carbono y son de gran importancia socioeconómica para las comunidades locales. La investigación tiene como objetivo analizar las estrategias de manejo forestal y sus impactos ambientales. El estudio se centra en los ecosistemas forestales en diferentes regiones y zonas climáticas. La metodología se basa en un análisis exhaustivo de la literatura científica, datos estadísticos y el examen de ejemplos prácticos. El artículo destaca la dinámica de la restauración de los ecosistemas forestales después de diferentes tipos de intervenciones en diferentes zonas climáticas, incluido el contexto ucraniano. Se evalúa el impacto de la gestión forestal en los balances globales de carbono y la esfera socioeconómica. La investigación muestra que las estrategias adaptativas pueden contribuir al desarrollo sostenible y la conservación de la biodiversidad. Las conclusiones proporcionan recomendaciones para la implementación de estas estrategias a nivel nacional, especialmente en Ucrania.

PALABRAS CLAVE: Biodiversidad, balances de carbono, silvicultura, impacto socioeconómico, evaluación estratégica, desarrollo sostenible.

Introduction

In today's world, the emphasis on sustainable development is becoming increasingly important in light of global environmental challenges such as climate change, loss of biodiversity, and pollution. Forestry is one of the critical sectors that can influence these parameters that define the quality of our environment. The management of forest resources plays a crucial role in preserving biodiversity, ensuring water resources, and regulating the carbon balance.

The chosen topic of studying the strategic assessment of the impact of forestry on the environment is pertinent. It allows the development of long-term approaches to the use of forest resources for sustainable development. Since forests serve not only as a source of income for the forestry industry but also as a vital component of the global ecological balance, strategic planning in this area becomes an integral part of the overall doctrine of sustainable development.

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Therefore, the purpose of this article is to examine and evaluate the potential impacts of forestry on ecosystems and to develop recommendations for the implementation of strategies that promote sustainable development in the context of forestry while preserving the ecological balance.

The study and understanding of this issue are essential steps toward achieving a harmonious coexistence between man and nature. Thereby, these steps ensure socio-economic progress and preserve natural resources for future generations.

To date, a significant amount of scientific research has been devoted to studying the impact of forestry on the environment, as outlined below. However, there are still some "white spots" that have not been sufficiently explored. These include, in particular, the dynamics of ecosystem recovery following active forestry interventions (especially under different climatic conditions) and the interrelationship between forestry and climate change (including the potential impact of forestry on global carbon balances). The social and economic consequences of strategic choices in forestry, in particular how they affect local communities and industry, also need to be studied.

The proposed study is based on the following hypotheses:

(a) Regarding ecosystem stability. Compared to traditional methods, contemporary forest management methods grounded in strategic planning and monitoring contribute to the support of biodiversity and the reduction of soil erosion.

(b) Concerning the socio-economic benefits of strategic planning. Strategic forest management, which considers ecological factors, leads to increased socio-economic efficiency. This type of management includes higher revenues for local communities and the creation of job opportunities.

(c) On the reduction of carbon dioxide emissions. This includes implementing strategies of balanced forest management, which encompass forest restoration and sustainable forestry practices. It results in decreased carbon dioxide emissions and enhances forests' capacity to assimilate CO_2 from the atmosphere.

-Aims

Our research aims to conduct an in-depth analysis of the impact of forestry on the environment in the context of sustainable development, as well as identify strategic directions for optimizing this impact, taking into account unexplored aspects of the issue. Accordingly, the objectives of our study are as follows:

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–to study the dynamics of ecosystem recovery following forestry interventions in different regions and climatic zones.

–to assess the impact of forestry on global carbon balances and its role in the climate change process.

–to study the social and economic aspects of forestry, especially its impact on local communities.

–to develop recommendations for the implementation of effective forestry strategies that contribute to sustainable development and biodiversity conservation.

1. Literature review

Given its importance, the topic outlined in the title is attracting considerable attention from scholars on both sides of the Atlantic. For example, F. X. Aguilar, A. Mirzaee, R. G. McGarvey, S. R. Shifley, and D. Burtraw (2020) note positive changes in the woodworking industry in the United States, particularly in pallet production. The authors emphasize the need for continued industry monitoring to ensure sustainable development and minimize negative environmental impacts. F. Babst, A. D. Friend, M. Karamihalaki (2020) convincingly argue that the ambitions of modeling forest impacts on the carbon cycle often exceed actual observations, signaling the need for better coordination between theory and practice to achieve sustainability.

H. Bugmann, R. Seidl, F. Hartig (2019) study submodels of tree mortality as a critical factor in modeling long-term forest dynamics. Their study evaluates 15 different models applied at different scales, from local to global. The conclusions of this study could be crucial for the strategic assessment of the impact of forestry on the environment. S. Burrascano, M. Chytrý, T. Kuemmerle (2016) show that current European policies are insufficient to promote carbon sequestration and biodiversity protection simultaneously. Searching for a hypothetical "middle ground," the authors emphasize the need to revise EU-level policies to achieve sustainable development in forestry.

M. Charru, I. Seynave, J. C. Hervé, (2017) demonstrate that recent growth changes in Western European forests are driven by climate warming. The research highlights the interconnection between climate change and forestry. D. Closset-Kopp, T. Hattab, G. Decocq (2019) focus on the impact of forest vehicles on changes in forest understorey

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between 1970 and 2015. This vital study draws attention to the dependence of changes on different environmental conditions and management. S. Etzold, M. Ferretti, G. J. Reinds (2020) assert that nitrogen deposition is the most crucial ecological factor influencing European forest growth. It underscores the need for monitoring and managing nitrogen emissions in the context of forestry.

A group of researchers led by R. Hanssen (2020) focuses on the potential of bioenergy with carbon capture and storage (BECCS) for climate change mitigation. They show that BECCS could be a key tool in combating climate change, particularly in emission-limited scenarios. L. Howard (2021) critically analyzes the assumptions behind the concept of carbon substitution in wood products. The author emphasizes the need for a deeper understanding of these mechanisms for the effective utilization of forest resources in CO_2 reduction. R. Hurmekoski and co-authors (2020) evaluate the impact of structural changes in the forest sector on net carbon emissions in Finland. They show that optimizing forest resource utilization could lead to emissions reduction. E. Jåstad (2020) examines the role of woody biomass in reducing the use of fossil fuels and greenhouse gas emissions in Northern Europe. The study observes that replacing fossil fuels with woody biomass could become a significant element in the emissions reduction strategy.

A research group led by T. Kalliokoski (2020) examines the climate change impacts of different Finnish forest harvesting scenarios, taking into account factors such as albedo, aerosols, and trade-offs between carbon uptake and emission avoidance. They emphasize that optimal forest use can contribute significantly to mitigating climate impacts. M. Köhl, S. Linser, K. Prins, and M. Talarczyk (2021) analyze the dual impact of the EU's "Fit for 55" package on European forests and the forest-based industries. They find that while the package aims to reduce greenhouse gas emissions, its impact on the forest sector may be complex.

D. Lawrence, M. Coe, W. Walker, L. Verchot, and K. Vandecar (2022) examine the hidden biophysical effects of deforestation on climate. They emphasize that land cover changes due to deforestation can have indirect but significant effects on the global and regional climate system. S. Luyssaert et al. (2018) examine the trade-offs in the use of European forests to achieve climate goals. They show that many choices and constraints need to be considered despite the potential to reduce emissions.

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T. Myllyviita, S. Soimakallio, J. Judl, and J. Seppälä (2021) investigate the potential of wood substitution to reduce greenhouse gas emissions. They review the current status and application of substitution factors and analyze their effectiveness and limitations. F. Pendrill, U. Persson, J. Godar, and T. Kastner (2019) focus on how global trade in forest-related products can displace deforestation. They examine the prospects for a global forest transition and its implications for climate change.

H. Pretzsch, P. Biber, G. Schütze, J. Kemmerer, and E. Uhl (2018) show that the volume growth of trees in central European forests has accelerated since 1870, while forest density has decreased significantly. This suggests potential changes in forest ecosystem conditions and may have implications for commercial timber use. S. D. Rittenhouse and A. R. Rissman (2015) examine how changes in winter conditions may affect the management of temperate forests. They argue that adaptation to these changes is essential for effective forest management.

L. Rosa, D. L. Sanchez, and M. Mazzotti (2021) assess the potential for carbon dioxide removal through bioenergy with carbon capture and storage (BECCS) in a carbon-neutral Europe. They discuss the possibility of significant emission reductions using this technology. S. Senf and R. Seidl (2021) map disturbance regimes in European forests. They analyze various factors affecting forest stability and recovery, including climate change and human activities.

A group of researchers led by A. Sommerfeld (2018) is studying the drivers of recent disturbances in temperate forests on a global scale. They look at different disturbance causes, including fires, pests, and logging. A. Tolvanen, M. Saarimaa, S. Tuominen, and K. Aapala (2020) question whether 15% restoration is sufficient to provide habitat for red-listed plant species in boreal peatlands. They emphasize the need for further research on this issue. P. Verkerk, M. Hassegawa, et al. (2021) consider the role of forest products in the global bioeconomy. They analyze how wood-based products can contribute to achieving the UN Sustainable Development Goals.

S. Xie, W. Kurz, and P. McFarlane (2021) examine two different bioeconomic strategies for the forest sector in British Columbia: domestic or external market orientation. They analyze this from the perspective of carbon storage and emissions in wood products. K. Yu, W. Smith, et al. (2019) identify overall reductions in carbon turnover time in living vegetation across forests in different climate zones. They may have significant implications

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for global carbon budgets and climate change. Z. Zhu, J. Peñuelas, et al. (2016) investigate the "greening of the Earth" and its driving forces. They point to the increase in the volume of vegetation on the planet, which can have multiple impacts on climate change, mainly through increased or decreased carbon uptake.

In addition to the aforementioned literature, the European Commission's reports (European Commission, 2020a; 2020b; 2020c; 2021a; 2021b; 2021c) cannot be overlooked, as they present the results of the 2030 Strategy, which aims to raise the EU's climate ambitions and revitalize nature for people. These documents provide an essential context for strategic planning in forest management at the European level.

2. Methodology

The research methodology consists of two main components: theoretical analysis on the one hand and synthesis and recommendations on the other. In turn, our study of the scientific literature includes the following:

1. Analysis of available sources, scientific-practical articles, and other publications related to the impact of forestry on the environment;

2. Identification of key trends, challenges, and primary determinants related to the research topic.

Analysis of existing data involves examining statistical information in the form of reports on forestry practices in different regions, as well as identifying key patterns and relationships between forestry and its environmental impacts. In our case, such analysis is best done in the context of a comprehensive source analysis.

Finally, the synthesis and recommendations involve reconciling the results of the theoretical analysis with the current situation in the field of forestry, particularly in Ukraine. This process also includes forming a comprehensive picture of the interaction between forestry and the environment, considering all identified patterns, trends, and challenges. It's important to note that our developed recommendations are based on defining strategies and actions that can ensure an optimal balance between forestry needs and sustainable development. We will also try to create a system of specific steps to implement these strategies in practice, taking into account regional specifics, as well as social and economic factors.

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Thus, the methodology described aims at an in-depth theoretical analysis of the current state of the forestry sector and the development of practical recommendations to achieve sustainable development.

3. Results

3.1. Dynamics of ecosystem recovery after forestry interventions in different regions and climatic zones

One of the key aspects of sustainable development is the balanced management of natural resources, including forest ecosystems. Forests are essential for maintaining biodiversity, regulating climate, and supporting socio-economic stability. However, despite their importance, human activities, particularly forestry interventions, are constantly affecting forests. This section examines the dynamics of forest ecosystem recovery following forestry interventions in different climatic zones, including Ukraine.

In temperate forests, typical of most European countries and the northern part of the United States, recovery dynamics after logging or other forms of intervention vary. In these regions, recovery is often rapid due to moderate climates and high precipitation. However, interventions can lead to reduced biodiversity and changes in natural processes.

The situation is different in tropical forests. Due to high temperatures and humidity, forests respond quickly to interventions. However, without proper management and planning, rapid recovery can lead to the formation of secondary forests with lower levels of biodiversity.

Forests play a key role in ecological stability in Ukraine, which is characterized by a predominantly temperate climate with pronounced seasonal changes. As in temperate forests, forests recover relatively quickly after interventions such as logging or forest fires. However, ill-considered forestry interventions can have serious negative consequences. These include soil erosion, loss of biodiversity, and changes in hydrological regimes.

3.2. The impact of forestry on global carbon balances and its role in climate change

It is well known that traditional forestry practices, such as logging, can remove significant amounts of carbon from forest ecosystems. It reduces the forest's ability to absorb carbon from the atmosphere and contributes to greenhouse gas emissions through

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the decomposition and combustion of wood. On the other hand, sustainable forest management, including reforestation and timber harvesting, can increase the carbon sequestration capacity of forests. Sustainable forest management can reduce the impact on carbon balances and become part of the solution to climate change.

In Ukraine, where forests are a vital ecological and economic resource, choosing the right forest management strategy is critical. Integrated approaches that consider climatic, environmental, and social aspects can help optimize carbon balances and minimize the impacts of climate change.

Forestry, therefore, has a dual impact on global carbon balances and climate change. Choosing a strategy that leads to sustainable development can significantly reduce the adverse effects of forestry on the climate and become part of global solutions to combat climate change. Ukraine should pay special attention to this issue as a country with rich forest potential.

3.3. Social and economic aspects of the forestry sector: its impact on local communities

Forestry impacts ecological and climatic parameters and profoundly affects local communities' social and economic structure. In this section, we will explore how forestry influences the lives of people residing in or near forested regions.

Forestry can serve as a significant source of employment for local communities, especially in areas where other forms of employment are limited. Timber harvesting, processing, and the production of forest products can add substantial economic value to the local economy. In some cases, sustainable forestry can attract tourism, providing an additional source of income.

For many local communities, forests are part of their cultural and spiritual identity. The jobs and economic opportunities generated by forestry can contribute to social stability. Unsustainable forestry practices may restrict local communities' access to resources like firewood, medicine, and food that forests provide.

Forestry, therefore, has a complex and multifaceted impact on local communities. While it can bring economic benefits through job creation and industrial development, ill-considered interventions in forest ecosystems can lead to social and environmental

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instability. Considering local communities' needs and values, sustainable forestry can strike a balance between economic development and ecosystem conservation.

3.4. Recommendations for implementing effective forestry strategies contributing to sustainable development and biodiversity conservation

Given the importance of forests as ecological, economic, and social assets, the development and implementation of strategies to promote sustainable development is a top priority. This task is particularly relevant in the Ukrainian context, where forests also play a critical role in the provision of ecosystem services and biodiversity.

Indeed, effective strategies should include ecologically sustainable forestry practices, such as planned harvesting for forest restoration and biodiversity conservation. For example, through environmentally sustainable logging and restoration practices, a project has been initiated in the Lviv region to conserve rare tree species, such as the European hornbeam. In addition, the introduction of adaptive management based on systematic monitoring and scientific data analysis should be considered. According to the State Forestry Agency of Ukraine, adaptive management methods have contributed to a 5% increase in forest cover in the Zakarpattia region over the past decade.

Active involvement of local communities in decision-making processes, including resource and biodiversity management, is also crucial. For example, the local community has taken responsibility for managing small forest plots in the Chernivtsi region. It has led to improvements in their condition and increased biodiversity.

The strategies for achieving sustainable development and biodiversity conservation in Ukraine's forestry sector must be versatile, scientifically grounded, and interconnected. It includes ecologically sustainable forestry practices, adaptive management, and meaningful participation of local communities. Global best practices demonstrate the effectiveness of such an approach.

3.5. Discussion on a strategic assessment of forestry's impact on the environment within the context of sustainable development goals

In the Ukrainian context, several aspects of the strategic assessment of the environmental impact of forestry should be discussed in more detail. First, ecologically sustainable management methods show high efficiency in certain regions, such as Lviv and

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Zakarpattia oblasts. However, these methods have yet to be compared with classical approaches at the national level, which makes it difficult to assess their overall effectiveness. Second, the implementation of adaptive management, while successful at the regional level, faces several organizational and financial challenges. The decentralization of resource management could lead to a lack of a unified strategy and an inability to respond to rapid ecological changes at the macro level.

Third, the active participation of local communities in forest resource management emphasizes the social component of sustainable development but also raises questions about the lack of skills or limited access to scientific and technical information among the local population.

Overall, the strategic assessment of the environmental impacts of forestry in Ukraine can serve as an essential step toward sustainable development, but it requires a more comprehensive, interdisciplinary approach. Particular attention should be paid to monitoring and evaluating the effectiveness of the methods used, as well as to promoting scientific-practical dialog among all stakeholders.

Conclusions

Our strategic assessment of the environmental impacts of forestry has identified key issues that need to be addressed to achieve sustainable development. Innovative forestry practices have shown positive results in certain regions. However, the lack of centralized evaluation of their effectiveness limits their potential for widespread implementation.

Adaptive resource management models, while promising, require further optimization in the face of financial and organizational constraints. The social dimension of forestry, including the involvement of local communities, remains under-researched and requires deeper scientific analysis.

The impact of forestry on global carbon balances and climate change has proven to be significant but complex to assess quantitatively without broader interdisciplinary research. Unfortunately, our work has been limited by data access and regional differences.

In the context of the practical significance of our findings, we emphasize the need to implement comprehensive monitoring methods and adaptive forest resource management at the national level. It is particularly relevant for Ukraine, where there is considerable diversification of forest ecosystems and local conditions. Taking into account local

specificities and involving local communities in the management process can significantly improve the efficiency of forest management and its impact on the environment.

We also recommend the development of interdisciplinary scientific programs that integrate ecological, economic, and social aspects for a comprehensive analysis of the impacts of forestry. It will enable the formulation of scientifically sound recommendations that can be implemented in practice.

The main directions of further research should focus on studying the socio-economic factors of forestry, their interaction with ecological parameters, and their impact on climate change. This could be a key factor in achieving sustainable development goals, especially for Ukraine, where forest resources are essential but not effectively managed.

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