



International experience and strategies for forest management in the context of growing forest pollution

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Abstract. The study aimed to analyse the foreign experience of forestry management and to address the latest strategies for managing forest resources. The positive experience of foreign countries in managing the forestry sector in the context of increasing forest pollution is highlighted. The possibilities of using this experience to improve legislation in the relevant field are considered. The study established that in the developed countries of the world forest resources are among the most important national values that have significant economic and socio-cultural significance. To effectively conserve and restore these resources, multilevel governmental mechanisms for managing forest resources in the face of increasing forest pollution have been introduced abroad. The study indicated that many developed countries use forest management strategies through an integrated approach to address this issue, the main essence of which is based on control measures carried out by both public authorities specialising in forestry and environmental safety authorities and services. The study noted that forest management in the world is becoming an increasingly urgent task due to the growth of pollution, climate change and other environmental challenges. Several international approaches and strategies used to preserve and restore forests are considered, namely: Sustainable Forest Management (SFM); forest certification; international treaties and initiatives; rehabilitation and restoration of forests; involvement of local communities; and technological innovations. Several important points of foreign experience in forest management that should be used and implemented in Ukraine are highlighted: the development of an agroforestry approach, the introduction of biodiversity conservation programs, the European Union's forestry development strategy, and others. The results obtained can be used to develop national and local forest management strategies, implement eco-standards, adapt pollution control plans, and raise awareness and education among citizens and government officials

Keywords: environmental sustainability; forest ecosystems; environmental policy; EU; environmental protection

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Introduction

The management of Ukrainian forest resources is an urgent issue of state regulatory policy, as they are an exhaustive and limited natural resource of the national economy. Furthermore, forest is an important component of the natural ecosystem of territorial communities, as it provides an opportunity to develop the economic and social sphere of many territories and sectors of the country, contributes to the conservation of biodiversity and provides a unique environmental microclimate (Ozkaya & Erdin, 2020). In the modern world, where technological and technical development is growing every day, forest resources are actively used for industrial purposes, which causes excessive deforestation, a decrease in the species composition of flora and fauna, pollution, and disruption of the natural balance of ecosystems. Incompetent management of forest resources leads to several negative consequences: soil depletion, reduced water retention function of territories, air and environmental pollution, and other negative factors for ecosystems and humanity in general.

Notably, state forest management strategies significantly impact the entire national economy, as these resources are the raw material base for many industries, such as forestry, fuel and energy, medical, cosmetics, pharmaceutical, food and other industries, which provides job creation in local communities, and a significant share of forest resources form a large part of Ukrainian exports (Shi *et al.*, 2022). The Ukrainian forestry sector remains in a critical situation. Forest resources do not meet economic and environmental requirements. Over the past 1000 years, the forest area has decreased by more than three times, forest landscapes have been subjected to anthropogenic changes, natural productivity has declined, and biodiversity has been reduced. Forest plantations have been destroyed by excessive deforestation in the past, so their natural protective functions are lower. Due to a lack of investment, reforestation and afforestation rates remain low, and the mismatch between the forest resource base,

forest development opportunities, and forest consumption is deepening (Torres *et al.*, 2021).

The study of the newest component of the strategy for the rational use of forest resources has been a part of research at the foreign and national legislative levels, as well as in the works of many scientists. There are many views among researchers on the strategy of the modern development of the forest industry, as well as the experience of their implementation abroad. O.V. Boyko (2021) believed that the creation of a modern, innovative forestry complex is possible only when the right legislative framework is created, a wide range of various subsidies is used, long-term programmes for the careful use of forest resources are created, and modern innovations in the forestry complex are monitored on an ongoing basis. M. Dyachenko *et al.* (2021) indicate that for the optimal functioning of the forestry sector, it is necessary to create free access to timber, but only if fair competitive conditions are created, a favourable climate for investment in innovative development is created, and positive dynamics of change is introduced, guided by the experience of European countries. Y.V. Muravyov *et al.* (2023) recommend changing the plan for creating strategies for the development of forestry institutions. This plan has a regional overtone, addressing the main features of the forestry sector in the Zakarpattia region. As a result of the study, a scheme of a modern strategy for the development of the forestry sector in the Zakarpattia region was proposed. The researchers also focused on international experience. O. Oshurkevych-Pankivska *et al.* (2023) have similar views, believing that in the process of creating an innovative policy for the development of the forest industry, it is necessary to address the uneven areas of forest plantations in different regions of Ukraine, which determines the necessity of keeping the focus on the regional levels.

D. Wuepper *et al.* (2023) argue that it is advisable to use a variety of approaches to the development of the forestry sector, accounting for the experience of foreign countries. They believe

that their implementation is justified in the face of risks and uncertainty of modern realities. The scientists believe that the following schemes for the development of this industry would be appropriate: export orientation, import substitution, and organisational and legal regulation. Similar views are shared by Y. Polishchuk *et al.* (2020). They believe that regional policy should be based on the experience of European partners, taking into account the following points: human capital development; subsidies for small and medium-sized businesses; modernisation of research by increasing investment; and forestry is seen as an object of modern smart specialisation. L. Malyuta & Y. Spyrudonova (2011) insist on the special importance of the forest, so it is necessary to use the latest methods in the forestry industry, which will have a positive impact on the production of fixed assets, money in circulation, increase productivity, reduce existing costs, and, of course, increase the estimated amounts. Scientists advise simulation, modelling, optimisation and digitisation of forest data, all of which will allow for the modelling of the latest forest systems.

Thus, the literature review shows that forest management issues have been considered by many researchers, but over time, forest management approaches and strategies have become outdated and need to be modernised. The study aims to analyse international experience in improving the forestry sector and to study modern forest management strategies, which will improve the forestry complex of Ukraine.

Materials and Methods

The study of international experience and strategies of forest management was based on natural materials and methods: a comparative analysis - to investigate investment and regulation of forestry opportunities in a market economy; analysis and synthesis of statistical information collected and processed to illustrate the current situation and trends in forestry in Ukraine; economic and statistical – to assess the current situation with forestry in Ukraine and its regions;

cause and effect – to create and analyse tools related to the creation of strategies for the development of forest potential and the effective reproduction and use of forest resources; graphs for displaying the results of scientific research; assessment of the effectiveness of organisational and economic instruments of state regulation of forestry activities in the region.

Geographic Information Systems (GIS) technologies were used in the course of this study. Notably, the main purpose of GIS was to produce and maintain databases with spatially coordinated information. Among the databases of this type were digital atlases created for different countries and published by Delorme Mapping Systems as part of the Domesday project (Lausch *et al.*, 2017), including the Digital World Atlas and the Digital Atlas of the United Kingdom. These databases also contained a digital format of the National Atlas of Ukraine, developed by the Institute of Geography of the National Academy of Sciences of Ukraine in cooperation with “intelligent geographic systems” (Massey *et al.*, 2023). The second important component of such a database is an observational system, such as the UNESCO-led Global Resource Information Data Bank (GRID) or the European Community Geographic Information System CORINE (Carvalho *et al.*, 2021). GIS functions also included the production and operation of cadastre systems integrating various fields: municipal automated information systems (MAIS), automated land information systems (ALIS), and spatially distributed automated information systems for cadastres (water, forestry, real estate). The spatial data software included GIS packages such as MGEIntergraph, ILWIS (Netherlands), MapInfo (USA), Arc/INFO, SICAD (Germany), ArcView GIS, and QGIS (USA).

Modern approaches, methods and materials based on the latest scientific studies were used to obtain the available results on the analysis of foreign experience and the most recent forest management strategies to use the positive experience gained in the forestry sector of Ukraine (Table 1).

Table 1. Regulations and forest management strategies of leading countries

Country	Primary regulatory acts	Primary forest management strategies
Canada	Forest Stewardship Council (FSC) (2024), Canadian Standards Association (2024)	Sustainable forest management, forest certification, investment in new technologies, cooperation with indigenous peoples
Finland	Programme for the Endorsement of Forest Certification (PEFC) (2024), FSC	"Cut down one tree – plant two", bioenergy investments, local community participation, environmental legislation.
Sweden	Forest Stewardship Council, PEFC	Sustainable forest management, investments in the latest technologies, environmental legislation, reforestation
Germany	National Forest Act (1975), Forest Stewardship Council, PEFC	Sustainable forest management, research, certification, forest rehabilitation, stakeholder engagement
France	Code Forestier (2024, November), National Wood Production Strategy (2024)	Sustainable forest management, certification, community engagement, research, climate change adaptation
Great Britain	The Forestry Commission (2024), UK Government's England Tree Strategy Consultation (2024)	Sustainable forest management, certification, community participation, education, climate change adaptation
USA	National Forest Management Act (NFMA) (1976), Forest Legacy Program (FLP) (1990), Forest Stewardship Program (2024)	National forest management, certification, fire management strategies, climate change adaptation

Source: compiled by the author

Acts of the Cabinet of Ministers of Ukraine and the Verkhovna Rada of Ukraine were used in the study, namely Forest Code of Ukraine (1994); the Law of Ukraine No. 1264-XII "On Environmental Protection" (1991); Resolution of the Cabinet of Ministers of Ukraine No. 303-2007-p "On Approval of the Rules for Forest Reproduction" (2007); Resolution of the Cabinet of Ministers of Ukraine No. 976-2009-p "On Approval of the Regulation on State Forest Protection, Forest Protection of Other Forest Users and Forest Owners" (2009) were employed in the study. Moreover, Statistical information from the State Committee of Forestry of Ukraine and regional forestry management institutions were used in this paper, namely the Public Report of the Head of the State Agency of Forest Resources of Ukraine for 2023 (2023) and reports of the State Statistics Service of Ukraine were employed in this research.

Results

The development of the forestry industry is an important component of many economies, and some of them have achieved significant success in this area thanks to effective strategies. Here are some

examples of the most successful countries and their strategies. Canada, which has some of the largest forest resources in the world, has several leading strategies for managing these resources (Yousefpour *et al.*, 2020). Canada is actively implementing sustainable forest management practices. Many Canadian forests are certified according to the Forest Stewardship Council (2024) and Canadian Standards Association (2024) standards, which guarantee environmentally responsible, socially beneficial and economically sound forest management. Canada is making significant efforts to preserve biodiversity. Government agencies are creating national parks, protected areas, and protected areas where deforestation is limited or prohibited. Canada is investing in research and development of new technologies for sustainable forest management, such as bioenergy projects, development of new wood materials and innovative methods of logging and forest management. Canada actively cooperates with indigenous peoples, involving them in the management of forest resources. Indigenous communities have the right to participate in decision-making on forest use, as well as to benefit economically from forest

resources. The country supports a policy of planting new trees in areas where deforestation has taken place to ensure forest regeneration. The country is conducting genetic research to grow more resilient and productive forest stands. Through these strategies, Canada not only conserves its forest resources but also provides economic benefits to its citizens.

Finland is a role model for forest management. The country contributes significantly to green forest preservation. The main aspect of forest management in Finland is deforestation, which is always accompanied by planting new trees. The “Cut down one tree, plant two” is the basic principle that Finland follows in managing forest resources. Most Finnish forests are certified according to PEFC or FSC standards. This ensures that forest management meets environmental requirements, and social principles and is economically viable. To improve the forestry industry, financial institutions are actively investing in new technologies and research. The main areas of investment include bioenergy, the creation of new materials from wood waste, and much more. Local communities are actively involved in the proposal and decision-making processes for forest management. They can express their opinions and participate in various activities, which improves their understanding of the value of forests. Finland has developed strong environmental legislation that has played a major role in shaping forest management strategies. High standards and strict laws regulate logging and forest management. This contributes to biodiversity conservation and ecosystem protection. Finland's forest management strategies include biodiversity protection, i.e., they create protected areas and operate various environmental programmes to preserve endangered and rare species of flora and fauna. Finland is indeed a role model for forest management (Dufour-Kowalski *et al.*, 2011).

Sweden is one of the countries that pioneered the principles of sustainable forest management. The basic principle is that deforestation should be compensated by reforestation. This ensures a

balance between deforestation and reforestation and preserves ecological systems and biodiversity. This principle is similar to the Finnish example of forest management. Most Swedish forests are certified according to the Forest Stewardship Council (2024) and the Programme for the Endorsement of Forest Certification standards. This guarantees that forest management is carried out responsibly, respecting environmental and social aspects, as in many European Union countries. One of the areas of sustainable forest management in Sweden is investment in research and development of the latest technologies in the forest industry. The country is developing new wood products, such as bioplastics and textile fibres, and is researching new wood processing methods to improve quality and reduce waste. The national environmental laws are strict, controlling deforestation, protecting water resources and monitoring biodiversity. The laws set strict limits and requirements for forest users to ensure the sustainability and longevity of forest ecosystems. The Swedish reforestation programme is quite robust and includes planning for the planting of new trees in the areas where deforestation has occurred. These measures preserve forest areas and contribute to balancing the carbon cycle. Sweden uses the latest technologies to monitor the state of forest resources, involves non-governmental organisations and ordinary citizens in making management decisions, and promotes the development of small and medium-sized forestry enterprises, which supports regional economic development and creates additional jobs. Sweden's forest management strategies are export-oriented, which brings large revenues to the country. Adaptation of forestry to climate change and strategies to reduce emissions of harmful gases are important ideas in Swedish forestry legislation. Large areas of forests absorb carbon, which means that Sweden uses forests as a tool to combat its large carbon footprint in the atmosphere. Sweden's forest management strategies are quite effective, helping to conserve forest resources and ensure their sustainability and economic efficiency (Jourdan *et al.*, 2021).

The development of the forestry industry is an important component of the economy of many countries, and some of them have achieved significant success in this area due to effective forest management strategies. Analysis of international experience highlighted an example of the successful implementation of forest policy and its successful implementation at the external and internal levels in the European Union. It is worth noting that the basic principles of forest management in Europe were created several centuries ago by German experts, which is why Germany is called the “trendsetter” among the European Union countries.

Germany is one of the world’s leading countries in the field of sustainable forest management. Its approach and strategies are extremely systematic and include measures and approaches. Here are some of the main aspects of the German forest management strategy:

1. Sustainable forest management: Germany is boldly implementing the principle of sustainable forest management, which means that it strikes a balance in the environmental, social and economic spheres when managing forest resources. The country regularly monitors the state of its forests, plans deforestation and reforestation, and takes measures to protect flora and fauna.

2. Legislative framework: forest management is regulated at both the federal and state levels. The main laws of sustainable management are enshrined in the National Forest Act (1975).

3. Forest certification: many forestry enterprises in Germany are certified by the Forest Stewardship Council and the Programme for the Endorsement of Forest Certification. This ensures compliance with high environmental, social and economic requirements.

4. Rehabilitation and restoration of forests: degraded forests in Germany are being actively restored. Much attention is devoted to the use of local tree species to preserve biodiversity and make ecosystems more sustainable.

5. Research and innovation: the development of technological innovation and scientific

research is a priority for Germany as it contributes to effective forest management, and Germany is investing heavily in the scientific sector. This includes the use of satellite imagery, drones and geographic information systems for forest monitoring.

6. Stakeholder engagement: an important part of the strategy is to involve various stakeholders, from local communities to private forest owners, environmental organisations and businesses. This contributes to a more integrated and harmonious approach to forest management.

7. Education and awareness-raising: a major role is played in education and awareness-raising about the importance of forest conservation and restoration. This includes training programmes, educational campaigns and cooperation with schools and universities.

8. Economic incentives: to support sustainable forest management, Germany uses various economic incentives, such as additional benefits for forest owners and subsidies, as a sustainable management practice. The country has also always been actively involved in international cooperation in forest management, exchanging experience and knowledge with other countries (Schneider *et al.*, 2021).

It is worth noting the positive experience of managing the forestry complex in France. According to French law, the environment, landscapes, flora and fauna, their varieties and bio-balance are part of the national heritage, and the protection, restoration and management of natural resources is a task aimed at protecting and preserving the environment from possible threats of destruction.

France has a wealth of experience and a comprehensive approach to forest management that combines all the above principles. France is actively implementing the principles of sustainable forest management, which are aimed at preserving flora and fauna, productivity and environmental sustainability of forests. This includes regulating deforestation, reforestation and protection against soil erosion. The National Wood Production Strategy (2024) defines the main

priorities of forest management policy until 2026. The main goals include the conservation of forests, increasing their productivity, strengthening the links between forests and the economy, and enhancing adaptation to climate change. The legal framework and regulation of forestry in France is carried out through laws and regulations, including the Code Forestier (2024). This provides a legal framework for sustainable forest management and the protection of forest resources. As in Germany, many forests in France are certified by the Forest Stewardship Council (2024) and the Programme for the Endorsement of Forest Certification, meaning that France is also actively pursuing a forest certification policy. This helps ensure compliance with high standards of sustainable management.

The country actively involves local communities, private forest owners, environmental organisations and businesses in the forest management process. This contributes to a more harmonious approach and consideration of all interests. Public awareness and education are an important part of the strategy, and France invests in training programmes for foresters, public education campaigns and cooperation with educational institutions. It also actively supports scientific research in forestry and introduces technological innovations for forest monitoring and management. This includes the use of satellite imagery, drones and geographic information systems. There are various economic incentives to support sustainable forest management, including financial support for reforestation, subsidies and tax breaks for forest owners. It is worth noting that France is developing and implementing measures to adapt its forests to climate change, including the selection of drought- and pest-resistant tree species and the introduction of new management practices, which will help forests adapt to new conditions. France is also actively involved in international initiatives on forest governance, knowledge sharing and cooperation with other countries to support global forest resilience (Grünig *et al.*, 2024).

The UK has its unique forest management strategy based on the principles of sustainable development, biodiversity conservation and consideration of environmental challenges such as climate change. The UK is actively implementing the principles of sustainable forest management, which are aimed at maintaining an ecological, social and economic balance in forest management. This includes regular monitoring of forest conditions, control of deforestation and reforestation measures. Forest policy and strategy are coordinated by the Forestry Commission (2024), which is responsible for developing and implementing forest management strategies. It also provides advice to the government and private forest owners. The UK actively supports certification programmes, such as the Forest Stewardship Council (2024) and the Programme for the Endorsement of Forest Certification, which promote sustainable forest management and ensure compliance with high standards. The UK government has also developed the UK Government's England Tree Strategy Consultation (2024), which includes measures to increase the area of forests, conserve existing forest resources and increase their resilience to climate change. The UK actively engages local communities, private forest owners and various stakeholders in the forest management process. This includes consultations, joint projects and support programmes for local initiatives. The UK raises awareness of the issue and invests in educational programmes to help raise awareness of the importance of sustainable forest management. This includes training courses, online resources and cooperation with educational institutions, as well as supporting research in forestry and introducing the latest technologies for forest monitoring and management. Satellite imagery, drones and geographic information systems are used to detect changes in forests and plan conservation measures. The UK is developing and implementing measures to adapt forests to climate change. This includes the selection of resilient tree species, changes in forest management practices, and measures to increase the resilience

of forests to extreme weather. There are a variety of economic incentives to support sustainable forest management, including grants, subsidies and tax breaks for forest owners who adopt sustainable practices. The UK actively participates in international initiatives on forest governance, sharing knowledge and best practices with other countries. This contributes to the global sustainability of forests and the maintenance of international environmental standards. These measures and strategies help the UK to effectively manage its forest resources, preserve them for future

generations, and adapt to new environmental challenges (Ligot *et al.*, 2023).

Analysis of the development of the forestry sector in the United States of America demonstrated a significant emphasis on the national economy, contrary to Ukraine. This conclusion is based on the fact that the country is one of the largest timber producers in the world. The United States of America (USA) has a variety of forest management strategies that include public, private and local initiatives, as forests are owned by different entities, as shown in Figure 1.

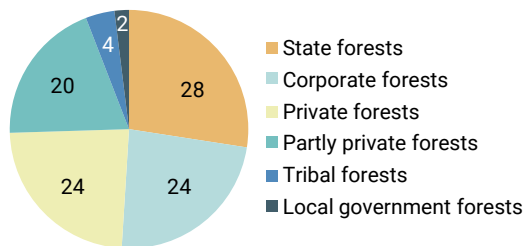


Figure 1. Ownership structure of US forests, %

Source: compiled by the author

These strategies aim to conserve wildlife and plants, use resources sustainably, and adapt to climate change. The US Forest Service is the primary agency responsible for managing 193 million acres of national forests and rangelands. It develops long-term forest management plans that consider environmental and societal considerations. The National Forest Management Act (NFMA) (1976) controls the management of public forests, dictates requirements for forest resource planning, and ensures public participation in decision-making. The National Park Service manages a system of national parks and wildlife refuges that include large areas of forests, which helps to preserve natural landscapes and biodiversity. The Forest Legacy Programme (FLP) (1990) is unique in that it aims to preserve private forest lands that have high ecological, recreational or historical potential. The programme provides financial support to protect forests from deforestation. There is also the Forest Stewardship Programme (2024), which provides technical and financial assistance

to private forest owners to develop and implement sustainable forest management plans. Like other countries, the US actively uses forest certification systems such as the Forest Stewardship Council (2024) and the Sustainable Forestry Initiative. This helps to ensure that forest resources are used appropriately. As fires are a serious threat to US forests, the National Forest Service and local governments are actively working to develop fire management strategies that include fire prevention, controlled burns and emergency response, as this is a national concern. The United States is developing and implementing measures to adapt forests to climate change, including the selection of drought- and pest-resistant tree species, as well as the introduction of forest management practices that increase their resilience to atypical weather conditions. Forest management in the United States also involves cooperation between various federal, state and local agencies. This ensures that efforts are directed towards the conservation and sustainable use of forests

(Guignabert *et al.*, 2024). These countries demonstrate how effective strategies can contribute to the sustainable development of the forest industry, providing economic benefits and conserving natural resources.

As for Ukraine, the national forestry policy places greater emphasis on direct government intervention and the use of economic incentives for sustainable forestry. The main components of the forestry industry are woodworking, forestry, furniture, forest chemicals, and pulp and paper. The economic crisis of 1990 significantly reduced the production capacity of these industries. Therefore, to restore the sustainable potential of the processing units of the forestry complex, it is necessary to create a modern design of state regulation of institutional changes. The nature of state control over the use of natural resources and environmental protection is determined by the state environmental policy. In the context of attracting foreign experience, this system should be aimed at restructuring relations in the human-society-environment system. Today, there is a need to restructure administrative institutions with a methodology for implementing the principles of integrated environmental management. The state policy in the field of environmental management should be based on a stable system of regulations, but in the context of martial law and constant changes in the domestic and foreign policy situation, this system should be resistant to changes in environmental components and avoid potential crises. This is an effective way to overcome economic and environmental problems and regulate environmental management.

Forest resources are a set of resources that includes timber, fruits, berries, medicinal plants, mushrooms, honey, firewood and other useful forest products, as well as the natural conditions in which forests grow, such as water, soils, climatic conditions, air and water pollution, and biodiversity. Forest resources are of great importance for the economy, as they are important sources of food, materials for construction and manufacturing, and energy resources, and they provide

other useful functions, such as biodiversity conservation, water and air purification, climate regulation, and others. A huge part of the global forest resources is used to produce timber, which is widely used in construction, furniture and paper industries. In addition, forests provide habitats for more than 80% of the global species. Forest ecosystems also have the potential to reduce emissions and contribute to the fight against global warming (Marfina, 2011).

Ensuring sustainable forest management has a significant impact on creating a sustainable economy and preserving the environment. Efficient use of forest resources and protection of forests from careless use is a key challenge for the sustainable development of our planet. A specific feature of forest and ecosystem management in Europe is the concept of integration, which implies the need for different approaches to the potential for intensive timber production from forests designated for nature protection or recreation. In the European Union, forests are multifunctional, thus, when managing forest potential, ecological, economic and social functions of forests are addressed, all factors are analysed and management decisions are made to identify and achieve the specified goal (Fournier *et al.*, 2022). Analysis of the experience of the world's leading countries identified main principles of forest management, as shown in Figure 2. A detailed description of each principle is provided below.

Conservation of forests and biodiversity: this principle involves the preservation of natural ecosystems, protection from pollution, protection from human interference and other negative impacts on the ecosystem. Biodiversity conservation is important because forests are home to a large number of different species of animals and plants. Conservation of natural processes is also relevant as they contribute to soil fertility, water balance and other ecological processes. Ensuring the conservation of forests and biodiversity is important for sustainable development and securing the natural resource potential for future generations (Karas *et al.*, 2021).

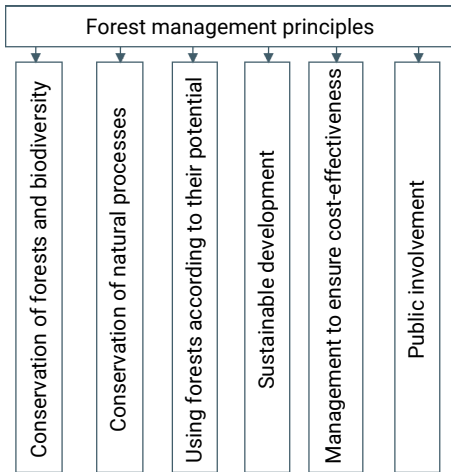


Figure 2. Basic principles of forest management

Source: compiled by the author

Use of forests according to their potential: this principle calls for the use of forests according to their purpose and capabilities. For instance, a forest can be used as a source of wood for furniture, paper and other materials, or as a recreational resource. This principle also requires consideration of the specifics of a particular area and forest. For instance, forests with more oak may be more profitable for furniture production, while forests with more pine may be better for paper and other materials. Analysis of the potential of forests allows to maximise the efficiency of their use and ensure the sustainable development of forest resources.

Sustainability: this principle implies that forests should be used at a rate that allows them to regenerate and maintain their ecological functions, including water and air purification, climate control, and biodiversity conservation. This principle is very important in forest management. Ensuring sustainable development means preserving natural resources for the long term, ensuring their use at a rate that does not exceed their natural ability to regenerate (Janová *et al.*, 2024). This helps to maintain ecological balance and ensure access to forest resources not only for current generations but also for future generations. To achieve this goal, it is necessary to apply

scientifically sound forest management methods that ensure their restoration and conservation. In addition, consideration of the impact of forestry on the environment and adherence to the principle of environmental safety are essential.

Management for economic efficiency: this principle implies ensuring maximum efficiency of forest resources use at minimum cost and maximum profit. The principle of management for economic efficiency implies that forest resources management should be aimed at ensuring maximum efficiency of their use with minimum costs and maximum profit. This implies the rational use of forest resources, optimisation of their extraction and processing, and increasing the competitiveness of the forest sector of the national economy. To achieve this goal, it is necessary to develop and implement effective forest management strategies, accounting for economic, social and environmental factors. It is essential to ensure effective control over the use of forest resources and the fulfilment of contracts for their extraction and processing, as well as to ensure transparency and openness in the process of resource allocation and control. Managing forest resources in an economically efficient manner can contribute to increasing forest revenues and developing the forest sector of the national economy. However, it is necessary to consider and consider environmental and social aspects, ensure the sustainability and conservation of forest ecosystems, and protect the rights and interests of local communities and forest users (Muys & Messier, 2023).

Public participation: this principle is essential to forest governance and involves the public in decision-making on forest management. This ensures that a wide range of diverse interests and perspectives, including economic, social, cultural and environmental, are represented, which are important for sustainable development. Public participation can take place through various forms of consultation, discussion and cooperation with stakeholders, including residents, representatives of civil society organisations,

academia and research institutions, industry and other interested parties. Public involvement helps to ensure broad support for decisions and builds trust in forest management processes. It also contributes to more effective and sustainable solutions that consider the needs and interests of different stakeholders and ensure the conservation and sustainable use of forest resources (Girma *et al.*, 2023).

Ukraine has several forestry management problems that affect the quality of the forest industry. The main problems of forest management are illegal deforestation, one of the biggest problems of forest management in many countries, including Ukraine. It leads to loss of biodiversity, disruption of ecological balance and reduction of CO₂ absorbed by forests. A major problem is insufficient protection of forests, which leads to a decrease in their natural value and deterioration of biodiversity. It also reduces the opportunities for sustainable use of forest resources and reduces the economic efficiency of forestry. Climate change is also a significant issue that has a negative impact on forests, in particular on their ability to store carbon and biodiversity. As a result, the risks of forest fires and diseases may increase, which can lead to increased forest loss. Unauthorised development of forest areas is quite popular in Ukraine, leading to a deterioration in the quality of forest resources and a decrease in their quantity, which leads to a decrease in the profits of forestry enterprises. Unauthorised development of forest areas is one of the most serious problems of forest management. This includes illegal deforestation, timber extraction without the necessary permits, the use of forests for illegal mining and other violations not provided for by law. The lack of alternatives to forest use can lead to unauthorised deforestation, which can be a barrier to sustainable development. For example, in certain regions of Ukraine, forests are the only source of firewood needed to heat domestic buildings in winter. In such cases, it is necessary to find alternative energy and fuel sources to reduce pressure on forest resources.

Discussion

The study demonstrated that international experience in managing forest resources against the backdrop of increasing pollution includes several effective strategies. Key outcomes include the introduction of air and water quality monitoring technologies, the use of innovative reforestation methods, and the integration of environmental standards into management policies.

The research showed that effective forest management strategies in the face of pollution often combined technological innovation with an integrated approach to resource management. For instance, the use of satellite data to monitor forest health has helped reduce pollution in the United States. NASA satellites such as Landsat have helped to reduce the percentage of pollution caused by deforestation and degradation, and in the state of California, Landsat data revealed a 20% reduction in pollution due to the control of forest fires and illegal logging. Sentinel-2 project in Australia is based on the use of the European Space Agency's Sentinel-2 satellites to help Australian researchers assess the condition of forests after forest fires. The data from these satellites allowed for a rapid assessment of the extent of damage and the implementation of restoration measures, which contributed to the restoration of 60% of the affected areas within the first year after the fires. Indonesia, in turn, uses satellite data to monitor forest changes and combat deforestation, so since 2015, thanks to satellite monitoring, the level of illegal logging in the country has decreased by 50%. Brazil has an Amazon forest monitoring programme, which uses satellite data to track deforestation, and thanks to data collected from satellites, deforestation in the Amazon decreased by 70% between 2004 and 2012 (Storch *et al.*, 2023).

The use of satellite data for forest monitoring is gaining popularity in Ukraine, and there are several notable examples: The National Forest Monitoring Project, launched in 2020, uses satellite data to track changes in forest cover. According to the project, from 2020 to 2023, more than

30,000 hectares of illegal logging and spontaneous deforestation were identified and documented. The Forest Map system, implemented as part of an initiative to improve forest governance, is also operating on our territory, and it is worth noting that satellite imagery helped to identify and assess a 15% reduction in forest area in Ukraine in 2022 due to military operations and illegal activities. Thanks to satellite data from the Copernicus project, 35 large forest fires were quickly detected and extinguished in 2021, helping to prevent further damage to over 5,000 hectares. These examples demonstrate that innovative satellite data technologies are helping to manage forests and respond to environmental challenges in Ukraine as well. This supports the hypothesis that monitoring technologies are key to effective forest management (European Forest Institute, 2024).

The conclusions are consistent with the research of modern scientists, both foreign and domestic. T.V. Vu *et al.* (2019), paid attention to the impact of air pollution on various aspects of forest ecosystems, including tree health and biodiversity. I.Z. Gitas *et al.* (2014) explored the latest remote sensing technologies for forest health monitoring and pollution assessment. In turn, S. Cunningham *et al.* (2015) analysed successful cases of forest restoration as a means of pollution control and environmental quality improvement. E. Muller (2024) compared environmental norms and standards in forest management in different countries. Also, D. Karnosky *et al.* (2003) reviewed the impact of pollution on the biodiversity of forest ecosystems at the global level. They also emphasised the importance of monitoring technologies in forest management.

D. Zadykhailo *et al.* (2023) addressing the impact of military operations on the state of forests and the possibility of satellite monitoring for damage assessment. R. Elijah (2023) analysing the role of satellite data in the processes of forest restoration after natural disasters and pollution. In turn, O.I. Bandurka *et al.* (2021), investigating the effectiveness of satellite technologies for

detecting and responding to forest fires. O.H. Chaskovskyy & H.H. Hrynyk (2020) examined the capabilities of Sentinel-2 satellites to assess the state of forests and their changes in recent years. Also, Y.S. Rajabova (2024) focused on the use of satellite imagery to monitor changes in forest cover and detect illegal logging. These studies show how Ukrainian scientists are using satellite technology to monitor and manage forests and assess environmental impacts. However, the study found that today, the war has a major impact on forest pollution. In Ukraine in particular, it has a significant impact on forests, causing physical damage through bombing and shelling, soil degradation and pollution, as well as increasing illegal logging and pressure on resources due to population displacement. The hostilities also reduce the capacity to manage and protect forests, leading to long-term environmental problems and requiring comprehensive efforts to restore forest ecosystems.

Despite the high relevance of this study, it is worth noting that certain limitations may affect its generality and applicability: first, the analysis was focused primarily on Ukraine and the European Union, which may limit the transferability of the findings to other regions of the world. Consequently, the results may not be fully reflective of the situation in other countries or continents where environmental, social and economic conditions may differ significantly. Secondly, data on forest pollution in some regions may have been incomplete or outdated, which may affect the accuracy and reliability of our findings. Future research should focus on the effectiveness of integrating different monitoring technologies in real-world settings, as this can significantly improve the quality of data collection and analysis, and it is important to investigate the impact of specific political and economic contexts on the success of forest management strategies in the face of pollution, which would allow for a better understanding of how different factors can interact and influence management decision outcomes. In summary, this study confirms that

effective forest management strategies in the face of increasing pollution can be achieved through the integration of technological innovations and a holistic approach. This is important for the development of new policies and practices that can be adapted to the specific conditions of different regions, which will not only contribute to the conservation of forest ecosystems but also increase their resilience to climate change and anthropogenic impacts.

Conclusions

Forest management is an important aspect of the national economy, as forests are a source of many resources, including timber used in construction and furniture production, as well as berries, mushrooms and other forest products used in the food industry. However, illegal deforestation and negligent management of forest resources can lead to environmental problems, such as reduced biodiversity, disturbance of ecological balance and reduced CO₂ absorption by forests, which in turn affects the climate.

In the process of analysing the international experience of forest management, the strategies of several countries were considered, namely: Canada, Finland, Sweden, Germany, France, the United Kingdom and the United States. Therefore, the following conclusions can be drawn: Canada focuses on sustainable forest management, forest certification, cooperation with indigenous peoples and investments in new technologies; Finland practices the principle of “cut down one

tree – plant two”, active involvement of local communities and high environmental standards; Sweden implements the principle of compensating deforestation with new plantations and investments in innovation, emphasising the importance of environmental legislation; Germany demonstrates a systematic approach to sustainable forest management, including monitoring, certification, reforestation and stakeholder engagement; France is noted for its comprehensive policy, including forest conservation, climate change adaptation and active education and research; The UK focuses on biodiversity conservation, investment in research and international initiatives; the US focuses on a combination of public, private and local forest management initiatives.

For Ukraine, these strategies can serve as useful examples for improving national forestry policy, especially in terms of sustainable forest management, certification, environmental monitoring and local community engagement. The prospect of further research is a detailed analysis of the possibilities of adapting international experience to Ukrainian conditions, to develop specific recommendations for the implementation of effective forest management strategies in Ukraine.

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Conflict of Interest

None.

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Міжнародний досвід та стратегії управління лісовими ресурсами в умовах зростання забруднення лісів

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Анотація. Метою даного наукового дослідження було ознайомлення з закордонним досвідом управління лісовим господарством та вивчення новітніх стратегій управління лісовими ресурсами. Виокремлено позитивний досвід іноземних країн щодо управління лісовою галуззю в умовах зростання забруднення лісів. Розглянуто можливості використання цього досвіду для покращення законодавства у відповідній сфері. Встановлено, що у розвинених країнах світу лісові ресурси відносяться до найважливіших національних цінностей, що мають значне економічне та соціокультурне значення. Для ефективного збереження та відновлення цих ресурсів закордоном запроваджені багаторівневі владні механізми управління лісовими ресурсами в умовах зростання забруднення лісів. У науковому дослідженні вказується, що в багатьох розвинених країнах використовують стратегії управління лісовими ресурсами за рахунок комплексного підходу до вирішення даного питання, основна суть якого, ґрунтується на заходах контролю, які здійснюються як органами державної влади, що спеціалізуються на питаннях лісового господарства, так і органами та службами з питань екологічної безпеки. У дослідженні зазначено, що управління лісовими ресурсами у світі стає все більш актуальним завданням через зростання забруднення, зміни клімату та інших екологічних викликів. Розглянуто кілька міжнародних підходів та стратегій, які використовуються для збереження та відновлення лісів, а саме: сталий лісовий менеджмент (Sustainable Forest Management, SFM); лісова сертифікація; міжнародні договори та ініціативи; реабілітація та відновлення лісів; залучення місцевих громад; технологічні інновації. Виокремлено декілька важливих моментів зарубіжного досвіду управління лісовими ресурсами, які варто використати та реалізувати в Україні: розвиток агролісомисленого підходу, запровадження програм збереження біорізноманітності, стратегія розвитку лісового господарства Європейського Союзу та інші. Отримані результати можуть бути застосовані для розробки національних і локальних стратегій управління лісами, впровадження екостандартів, адаптації планів боротьби зі забрудненням, а також для підвищення обізнаності та освіти серед громадян і представників влади

Ключові слова: екологічна стійкість; лісові екосистеми; екополітика; ЄС; охорона довкілля