

SUSTAINABLE FORESTRY: PRINCIPLES AND METHODS

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Introduction

Sustainable forest management is of key importance to maintain the long-term ecological, economic and social roles of forests, contributing to environmental balance, economic benefits and community well-being. Sustainable forest management is the practice of managing and using forests to meet current needs while ensuring that forest health, productivity and biodiversity are maintained for future generations. This approach takes into account the ecological, economic and social role of forests and aims to manage forest areas in a sustainable way in the long term. In this study, we aim to present forestry practices that contribute to the long-term conservation of forests and meet international sustainability criteria. To achieve our objective, we used qualitative research and conducted expert interviews.

A Review of Literature

The classical and conscious interpretation of sustainability is the complex unity of the environment-society-economy triad (Bándi, 2013). Ecological sustainability refers to the conservation of forest biodiversity, ecological processes and health, including the protection of the soil, water and air quality (Daily and Ehrlich, 1992). Economic viability is nothing less than the provision of the economic aspects of forest management, including the sustainable production of wood-based and non-wood products and the support of local communities' livelihoods. Finally, social responsibility means taking into account the social aspects of forest management and use, including the involvement of local communities, respect for indigenous peoples' rights and equitable distribution of forest resources.

Sustainable forest management practices are supported and regulated by a number of international organisations and guidelines, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). These organisations offer a range of certification schemes to ensure that forest management practices meet sustainability criteria.

The literature-based concepts of sustainable forest management may be more detailed and complex than general descriptions. Academic and professional sources generally approach sustainable forest management from multiple perspectives (Makszim and Soós, 2025), including ecological, economic and social aspects. In the following, I aim to explain the concepts in more detail based on the literature.

Ecological sustainability has two aspects: biodiversity conservation and maintenance of ecological processes (Soós and Nagyné, 2024). Biodiversity conservation means that sustainable forest management ensures that forest biodiversity is maintained, including the conservation of plant and animal species as well as the protection of ecosystems and habitats (Spellerberg and Hardes, 1992). The spread of invasive plant species and the loss of natural habitats increase the risk of the extinction of protected species. *Ex situ* conservation and targeted propagation in botanical gardens are efficient complementary tools (Csabai et al. 2011; Farkas et al. 2025) and may also contribute to long-term studies of the impacts of invasive species (Cseceserits et al.

2018). Maintenance of ecological processes refers to the maintenance of ecological functions and processes (e.g. nutrient and hydrological cycles) in forests for long-term sustainability (Noss, 1990).

Economic sustainability means economic profitability on the one hand and resource efficiency on the other (Soós, 2023). Economic profitability means that sustainable forest management ensures that the economic activities of the forests remain profitable in the long term, including the production of wood-based and non-wood forest products. Resource efficiency refers to the more efficient use of resources in management practices, minimizing waste and maximizing yield (Davis and Johnson, 1987).

Social sustainability also has two essential contents: one is community participation and the other is social justice (Moravec, 2022). Community participation is the process by which sustainable forest management promotes the involvement of local communities in decision-making processes, ensuring that the interests and traditions of communities are respected (Colfer and Capistrano, 2005). Social justice essentially refers to the equitable distribution of forest resources, taking into account the rights and needs of different social groups (e.g. indigenous peoples, minorities) (Shiva, 1988).

Sustainable Forest Management Principles and Practices at International Level

Based on its international literature, sustainable forest management principles and practices include a number of specific methods and approaches to ensure the long-term sustainability of forests. Below are some of the key practices and strategies that are widely recognised and applied in different parts of the world.

One of the most important principles in forest management is the principle of reforestation, which means restoring felled or degraded forest areas by planting native species. The planting of native species and natural regeneration help to restore the original ecosystem and biodiversity (Lamb and Sutton-Smith, 2014).

Ulrich Mergner, in his 2021 book *Das Trittsteinkonzept* [The Stepping Stone Theory], describes his 30 years of experience in forest management and confirms three basic forest management theses with sustainability in mind. In his work, he stresses that forest management integrated with conservation is more efficient in maintaining and enhancing ecological diversity and more efficient in management than passive conservation or purely profit-oriented governance is. Protecting many small areas or leaving them out of production will result in much greater biodiversity than a passively protected 'forest reserve' of the same area. The management following his principles significantly increases the ecological diversity of forests - and hence their natural value - and with it their resistance to all kinds of damaging impacts.

Target-diameter harvesting is used to fell only specific sizes and species to minimise disturbance to the ecosystem. The trees suitable for felling are identified, taking into account species composition and their regeneration capacity (Putz et al. 2012). This method minimizes damage to forest structure and biodiversity and is very widespread in different parts of the world, for example, outside Europe it is often used in the Amazon rainforest or the Congo Basin, too.

Landscape-scale planning is a strategy rather than a practice, based on a landscape-scale approach to forest management that takes into account ecological contexts and the impacts of surrounding areas. In practice, ecological corridors are created and protected areas are designated for sustainable development. This approach is used in North America and Europe, focusing on the establishment of a network of protected areas and the maintenance of ecological corridors (Forman, 1995). In Hungary, this planning is applied in a similar manner: during district forest planning, the tasks and opportunities that may be done in the forests of the forest planning district are planned every 10 years in a way that harvesting may be balanced and sustainable in the entire district. Specifications are set for the whole district, e.g. how much forest area not serving timber production should be selected.

Among the practices, it is important to highlight forest protection measures, such as regular monitoring, the use of biological control methods and the development of fire prevention strategies — mainly aimed at preventing various pests, diseases and natural disasters. Certification schemes are also a best practice, both applying and monitoring sustainability standards in management practices. The FSC (Forest Stewardship Council) or PEFC (Programme for the Endorsement of Forest Certification) was established to promote responsible forest management, ensuring compliance with sustainable practices and increasing market access. In addition to environmental protection, economic, social and human rights considerations are also important criteria in the FSC and PEFC standards (Fodor, 2015).

Community forestry is about actively involving local communities in forest management and decision-making. That is ensured through a range of education and training activities to promote community interests and sustainability. It is a method used in Nepal and Mexico, Canada and Sweden, which integrates the ecological balance of forests and the long-term health of ecosystems (Grumbine, 1994). It is similar in Hungary, too: at certain stages of the forest planning process, civil society can have a say and comment, and planning is done in a quasi-public manner.

Finally, monitoring and adaptive management is a method of continuously reviewing and modifying forest management practices in the light of experience and new scientific results. Adaptive management methods used in the United States and Australia continuously evaluate and modify management plans for sustainability (Holling, 1978).

These methods and practices cover different aspects of sustainable forest management and aim to maintain the long-term health and productivity of forests, while ensuring economic and social benefits.

Sustainable Forest Management Practices in Hungary

In Hungary, the practice of sustainable forest management includes a number of specific methods and approaches to ensure the long-term ecological, economic and social sustainability of forests. Below we detail the most important sustainability practices that are decisive from the viewpoint of the long-term strategy of forest management in Hungary.

Close-to-nature forestry means that forest management practices favour natural processes and native species, for example by promoting oak (*Quercus*) and beech (*Fagus sylvatica*) as native species and discouraging alien species such as acacia (*Robinia pseudoacacia*).

Target-diameter (selective) harvesting, reforestation, landscape-scale forest management, community forest management, the application of forest protection measures and certification schemes are also present in Hungary, in line with international practices. Selective logging is exemplified by *Pilisi Parkerdő* [Pilis Park Forest]; projects in *Duna-Dráva Nemzeti Park* [Duna-Dráva National Park] to restore floodplain forests (Internet1) illustrate reforestation. It is in *Aggteleki Nemzeti Park* [Aggtelek National Park] that landscape-scale planning and ecological corridors aiming to ensure the free movement of wildlife and the conservation of biodiversity have been introduced. Examples of community forestry practices include the Börzsöny Mountains and those of forest protection measures *Mátrai Tájvédelmi Körzet* [Mátra Landscape Protection Area]. Several Hungarian organisations are FSC certified.

Adaptation to climate change is a method of changing forest management practices to mitigate the effects of climate change and increase the resilience of forests. Planting drought-tolerant tree species and improving forest water management, for example in *Kiskunsági Nemzeti Park* [Kiskunság National Park], are good examples of climate-smart forestry (Internet2).

Why Is Sustainable Forest Management Approach Important?

Forests are home to a significant proportion of the Earth's wildlife and play an important role in conserving biodiversity. Sustainable forest management ensures that habitats and species are maintained. Forests provide ecosystem services such as water filtration, soil protection, carbon

sequestration and oxygen production. They play a significant role in mitigating climate change by capturing and storing large amounts of carbon dioxide. Sustainable forest management contributes to climate change mitigation. In addition to ecological considerations, it is also economically rewarding to use sustainable methods, as these solutions contribute to a more efficient use of forest resources, minimizing waste and maximizing yields. Farmers and companies adopting sustainable forestry practices can often have advantageous market access and competitiveness, especially in markets where sustainability certifications are valued. On the social-welfare side, forests are the main source of livelihood for many local communities, while they also have significant cultural, recreational and health values. Sustainable forest management ensures that these communities can benefit from forests in the long term without depleting them. Sustainable management practices are based on the principles of community participation and equity, involving local communities in decision-making and ensuring that their interests and rights are respected. Ultimately, the sustainable use of forests contributes to social well-being by ensuring the long-term use of forest land and the economic stability of communities.

Material and method

To support our objectives, we conducted qualitative research through expert interviews. Qualitative research is an exploratory method that will not produce quantitative outputs. It is a qualitative and not a quantitative approach. It is based on a small sample and aims at understanding the problem (Makszim, 2019). The reason for choosing this methodology was clearly to explore the practices of sustainable forest management through the example of *Nyírerdő Erdészeti Zrt.* [Nyírerdő Forestry Company], involving experts (forest engineers). The interview was conducted in a semi-structured format, based on pre-set questions, but, as a matter of course, there were also some open-ended questions of the interviews beyond the questions. The subjects of the expert interviews were three certified forest engineers from Nyíregyháza Forestry of *Nyírerdő Zrt.* Applying their expertise, experience and deep commitment to sustainable forest management, they answered our research questions. The expert interviews took place in June 2024 and lasted 45-50 minutes.

Results and their Evaluation

To understand the methods and principles of sustainable forest management, I conducted expert interviews with three forest engineers of *Nyírerdő Zrt.* along semi-structured questions. The qualitative research and its questions revolved around four main themes:

1. Planning sustainable forestry;
2. Sustainability rules;
3. Changes in sustainability practices and devices;
4. Precision forestry.

Planning, or the Cornerstone of Forestry

The first step in the complex process of forest management is the planning phase, which is used to manage the forest in a given area (district). The document itself is called district forest plan, which precisely describes each forest area in terms of what operations and tree species are to apply and in how large area. It is a long-term strategic plan covering a 10-year period. Forest planning aims to ensure the sustainable use and protection of forests, taking into account ecological, economic and social aspects.

The management of *Nyírerdő Zrt.* is characterised by a trend of increasing timber volume, as an important principle in their approach is to deliberately leave forest areas without human intervention for a longer period of time. An important basic rule is to replace a forest with another one within two years. The principle of proportionality in planning can be traced, so in practice

160-170 hectares are planned for final use per year, approx. 70 per cent of which is actually realized. They also stressed the long-term objective of favouring native species over alien species in management.

The Legal Framework for Sustainability

Natura 2000 areas (e.g. *Sóstói Erdő* [Sóstó Forest]) are dominant among the areas managed by *Nyírerdő Zrt.*, where special rules and environmental regulations apply to all work phases, from soil preparation to stumping.

The *Nyírerdő Zrt.* is FSC-certified, a system that assesses the quality of forest management and at the same time demonstrates its commitment to sustainable development. The standards system is based on environmental awareness, sustainability and responsibility for maintaining ecological balance. This principle is at work in *Nyírerdő Zrt.*, where, with the felling of young or sick trees being necessary, replanting is also ensured, preserving biodiversity. The FSC certification not only imposes strict rules on the use of chemicals, but also stipulates that indigenous populations should be given preference in employment.

Sustainability Practices and Methods

The choice of forest management practices is fundamentally determined by the specificity of the sandy soils of *Nyírség*, so the effects of climate change are particularly pronounced here, in the following ways:

- The loose, sandy soil of the *Nyírség* region drains water quickly. The decreasing annual precipitation and the uneven distribution (long periods of drought followed suddenly by high amounts of rainfall) exacerbate soil drying. This affects tree growth and reduces the chances of natural regeneration.
- Warmer weather increases evaporation, further reducing the moisture available in the soil. The lengthening of the growing season means that trees need water for prolonged periods of time, but it is not available.
- Traditionally planted species, such as acacia (*Robinia pseudoacacia*) or black pine (*Pinus nigra*), can resist arid conditions to an ever-decreasing extent. Some native species of the *Nyírség*, such as pedunculate oak (*Quercus robur*) or common hornbeam (*Carpinus betulus*), may decline or be maintained only artificially. At the same time, invasive species such as ailanthus (*Ailanthus altissima*), black cherry (*Prunus serotina*), common hackberry (*Celtis occidentalis*), box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*) have been spreading, which, in the absence of natural enemies, displaces native species and affects the ecological balance and economic value of forests. While knotweed (*Reynoutria japonica*) and oleaster (*Elaeagnus angustifolia*) are not very common, black cherry (*Prunus serotina*), box elder (*Acer negundo*), common hackberry (*Celtis occidentalis*), and indigo bush (*Amorpha fruticosa*) are a serious threat for the forest structure, the goals of conserving nature, and, very often, even for economic profit.
- The warming favours certain pests (e.g. European spruce bark beetle (*Ips typographus*), goat moth (*Cossus cossus*), which can cause large-scale forest destruction. Weakened trees become more susceptible to fungal and bacterial infections.
- Instead of natural regeneration, artificial reforestation is more often necessary, which is more costly but more certain to produce a result. The introduction of new tree species is not common at present, but the use of propagating material of native species from the south (Serbia, Bulgaria, etc.) has been considered.

Climate change is a major stress factor for forest holdings in the sandy regions of *Nyírség*. The key to adaptation could be agro-forestry, i.e. farming with a combination of agricultural crops and trees, e.g. poplar (*Populus*) and maize (*Zea mays*). In addition, it is a good practice in forest management to create climate-tolerant forest structures (heterogenous, mosaic, and mixed forests).

Precision Forestry

The use of modern digital solutions (drones, geoinformatics systems) has also become a key factor in forest management. High-resolution images collected by drones and satellites allow precise monitoring of forest conditions and changes. These tools help in the early detection of illegal logging and forest fires, as well as in monitoring regeneration processes and forest health. The use of digital technologies enables more accurate development and implementation of forest management plans and the monitoring of the progress towards sustainability goals.

Conclusions

The future of sustainable forest management faces several challenges and has a number of opportunities that determine how forest management can be further developed and adapted to changing environmental, economic and social conditions. Technological advances, including precision forestry and Big Data, could be trends that influence the future of sustainable forest management. The use of drones, remote sensing, GPS and GIS technologies will enable more accurate monitoring and management of forest conditions. These devices help to increase the efficiency of selective logging and forest restoration. Large-scale data collection and analysis can help to better understand forest health and growth and fine-tune sustainability strategies. Adaptation to climate change, with the planting of drought- and climate-tolerant tree species as an important element, can provide another direction for future forest management. Carbon sequestration, carbon dioxide credits and other financial incentives can help maintain forests and increase carbon sequestration.

In the future, valuating and integrating forest ecosystem services (e.g. water filtration, soil conservation, recreation) into economic models could help to support sustainability. Certification schemes such as FSC and PEFC are playing an increasingly important role in promoting sustainable practices. Increasing consumer awareness of sustainable products could further increase the importance of these certifications. The involvement of local communities in educational institutions is the key to educating them about sustainability (Moravec and Kovács, 2025), which ultimately contributes to the success of forest management. Involving communities and their young generations can ensure that forest management practices are essential to local needs and circumstances. The support of national and international policies and legislation is essential to promote sustainable forest management. These frameworks should encourage the use of sustainable practices and protect forests. Agro-forestry and integrated land management can promote sustainable management of forests and agricultural land, increasing biodiversity and soil fertility. International cooperation and programmes, such as the UN REDD+ programme, can help promote sustainable forest management and combat climate change. International knowledge sharing and exchange of best practices can help to improve forest management practices and promote sustainability.

Summary

The future of sustainable forest management is promising, but it faces many challenges. Technological advances, adaptation to climate change, economic and social support and innovative management practices can all contribute to the sustainable management and conservation of forests for future generations. Innovations in sustainable forest management help forests to maintain their ecological, economic and social role in the long term. New technologies, management methods and community approaches enable forests to serve current and future generations in a sustainable way.

Keywords: sustainable forest management, *Nyírség*, biodiversity, expert interview

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