

Report on socio-economic effects of forest management scenarios by CSA

D5.4



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Author(s)	Francesca Giannetti (BB), Ilaria Zorzi (BB), Niccolò Fani (BB), Stefanie Linser (BOKU), Mathias Neumann (BOKU), Marius Rohde Johannessen (USN)
Reviewed by	Vladut Falcescu (MeteoRo), Mar Riera Spiegelhalter (ENT), Alice Ludvig (BOKU), Marius Rohde Johannessen (USN), Mauro Morichetti (CNR), Alessio Collalti (CNR), Elisa Grieco (CNR), Mirabela Marin (INCDS), Indriany Lionggo (IEECP), Roberta D'Angiolella (IEECP)
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About OptFor-EU

OptFor-EU wants to co-develop a Decision Support System (DSS) with forest managers and other forest stakeholders, that provides them with suitable climate adaptation and mitigation options for science-based optimising forest ecosystem services (FES) (including decarbonisation) and enhancing forest resilience and its capacities to mitigate climate change across Europe.

The project 'OPTimising FORest management decisions for a low-carbon, climate resilient future in Europe (OptFor-EU)' will build a Decision Support System (DSS) to provide forest managers and other relevant stakeholders with tailored options for optimising decarbonisation and other Forest Ecosystem Services (FES) across Europe.

Based on exploitation of existing data sources, use of novel Essential Forest Mitigation Indicators and relationships between climate drivers, forest responses and ecosystem services, OptFor-EU has five specific objectives:

- Provide an improved characterisation of the Forest-Climate Nexus and FES;
- Utilise end-user focused process modelling;
- Empower forest end-users to make informed decisions to enhance forest resilience and decarbonisation;
- Provide a novel DSS service; and
- Bridging different EU strategic priorities, robust science, and stakeholders in the forest and forest-based sectors.

Based on a supply-demand approach, the methodology combines an iterative process of data consolidation, modelling, and co-development of solutions alongside forest managers and other practice stakeholders in all European Forest Types. The DSS will be designed and tested at 8 case study areas, to provide a ready-to-use service, near to operational (TRL7) at European level, while a user adoption and up-take plan will maximise the societal and business impact.

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List of Abbreviations

BAU	Business As Usual
BMC	Business Model Canvas
CSA	Case Study Area
DSS	Decision Support System
EFT	European Forest Type
EFMI	Essential Forest Mitigation Indicators
FES	Forest Ecosystem Services
FMP	Forest Management Practices
FMPla	Forest Management Plans
FSC®	Forest Stewardship Council
FTE	Full-Time Equivalent
GDP	Gross Domestic Product
IRR	Internal Rate of Return
MAI	Mean Annual Increment
MCDM	Multi-Criteria Decision-Making
NFI	National Forest Inventory
NPV	Net Present Value
NTFP	Non-Timber Forest Product
NWGS	Non-Wood Goods and Services
PES	Payments for Ecosystem Services
PEFC	Programme for the Endorsement of Forest Certification
PFS	Preferred Future Scenario
ROI	Return on Investment
SFM	Sustainable Forest Management
SoEF	State of Europe's Forests
TLS	Terrestrial Laser Scanning
WP	Work Package

Glossary

1.1.1 1 - Ecology

Term	Definition
Adaptive Forest Management (AFM)	A dynamic management approach adjusting silvicultural actions based on climate change, monitoring, and evolving ecological conditions.
Afforestation / Reforestation	Establishment of new forests (afforestation) or regeneration of harvested/degraded forests (reforestation).
Biodiversity Indicators	Metrics tracking species richness, habitat quality, genetic resources, and ecosystem naturalness.
Carbon Retention	Ability of forest ecosystems to maintain carbon stored in biomass, soils, and harvested wood products over time, by limiting carbon losses and delaying the release of CO ₂ to the atmosphere through forest management.
Carbon Sink	The net CO ₂ absorbed and stored by forests in biomass, soil, and long-lived wood products.
Closer-to-Nature Forestry (CTNF)	Management model emphasising structural diversity, continuous cover, and climate resilience.
Dehesa	Traditional Mediterranean agro-silvo-pastoral system combining trees, grazing, and crops.
Ecosystem Services (FES)	Benefits forests provide (timber, NTFPs, carbon sequestration, recreation, biodiversity).
European Forest Type (EFT)	EU ecological classification system describing forest types (boreal, hemiboreal, mesophytic, mediterranean).

Forest Disturbances	Wildfire, storms, droughts, pests, pathogens, often exacerbated by climate change.
Forest Management Plan (FMPla)	Official planning document describing management interventions, cycles, and objectives.
Mean Annual Increment (MAI)	Average annual increase in forest volume; key productivity indicator.
Natural / Assisted Regeneration	Renewal of forests through natural seed dispersal or human planting interventions.
Non-Timber Forest Products (NTFPs)	Products other than wood (resin, cork, mushrooms, honey, game, etc.).
Rotation Period	Time between stand establishment and final harvest in rotation forestry.

1.1.2 2 – Socio-Economic & Financial Indicators

Term	Definition
Business As Usual (BAU)	Current management/economic configuration without innovation or climate-driven transformation.
Carbon Pricing	Refers to mechanisms, emissions trading systems, or voluntary carbon markets that place a price on CO ₂ emissions or credits.
Case Study Area (CSA)	One of eight test regions in which OptFor-EU applies models, indicators, and scenarios.
Cost Efficiency	Balance between forest management costs and economic/ecosystem benefits.
Economic Multipliers	Measures of indirect and induced economic effects of forestry on linked sectors.
Employment – Full-Time Equivalent (FTE)	Standardised unit measuring employment as equivalent full-time workload.
Forest Product Diversification	Expansion of revenue sources beyond timber to include NTFPs and services.
GDP Contribution	Share of national GDP generated by forestry and wood-related industries.

Internal Rate of Return (IRR)	Indicator of profitability of long-term forest investments.
Land Abandonment Rate	Percentage of land no longer under active management.
Net Present Value (NPV)	Discounted value of long-term forest revenues minus costs.
Profitability / Revenue Indicators	Measures of net revenue, value added, and financial performance.
Return on Investment (ROI)	Ratio expressing financial returns relative to investment costs.
Socio-Economic Indicators	Measures reflecting employment, incomes, community well-being, and social resilience.
Timber Market Instability	Volatility affecting timber prices, profitability, and supply.

1.1.3 3 – Digitalisation, Modelling & Monitoring

Term	Definition
Decision Support System (DSS – OptFor-EU)	Digital tool integrating data, scenarios, and indicators to support forest decisions.
Digital Traceability	Technology-based tracking of wood and carbon along the supply chain.
Geospatial Analysis	Use of GIS and spatial modelling for forest mapping and scenario evaluation.
LiDAR (Light Detection and Ranging)	Remote sensing technology producing 3D biomass and structure data.
MCDM – Multi-Criteria Decision-Making	Analytical framework combining ecological, social, and economic indicators.
Scenario Modelling	Simulation of forest futures based on climate, management, and socio-economic assumptions.
TLS – Terrestrial Laser Scanning	Land-based LiDAR providing high-resolution forest structure data.
UAV / Drone Monitoring	Aerial remote sensing used for forest surveillance, biomass estimation, and fire detection.

1.1.4 4 – Governance, Policy & Institutional Terms

Term	Definition
Forest Europe Criteria (C1–C6)	International sustainability framework measuring resources, health, productivity, biodiversity, protection, and socio-economic functions.
Governance Efficiency	Ability of institutions to plan, coordinate, and implement sustainable forest management.
Ownership Fragmentation	Condition where forest property is divided among many small owners, reducing management feasibility.
Payments for Ecosystem Services (PES)	Compensation schemes for carbon, water, biodiversity or other public ecosystem benefits.
Planning Funds	Financial resources supporting forest management planning and implementation.
Protected Area / Unmanaged Forest	Zones under environmental protection where timber use is restricted or absent.
Public vs. Private Ownership	Institutional distinction shaping obligations, incentives, and management practices.
Risk Management Policies	Regulations and practices addressing wildfire, pests, drought, erosion, and climate risks.

1.1.5 5 – Business Models & Decarbonisation

Term	Definition
Bioeconomy	Economic system based on renewable biological resources replacing fossil-based materials.
Business Model Canvas (BMC)	Framework describing structure and strategy of a business model (value, partners, costs, revenues, etc.).
Carbon Credits / Carbon Market	Tradeable units certifying carbon sequestration or emission reduction.
Carbon-negative Bioenergy	Bioenergy combined with carbon capture, creating net-negative emissions.
Circular Economy in Forestry	System where wood is reused, recycled, and substitutes high-emission materials.

Decarbonisation Strategy	Integrated actions to increase carbon sequestration, reduce emissions, and shift to low-carbon materials.
Ecosystem Service Monetisation	Converting forest services into measurable, marketable financial assets.
Preferred Future Scenario (PFS)	Optimised scenario aiming for resilient, diversified, climate-smart forest management.
Value Proposition (Forestry)	The set of benefits delivered to users or society, such as timber, carbon, biodiversity or recreation.

EXECUTIVE SUMMARY

This first part of the deliverable (D5.4) provides a comprehensive assessment of the socio-economic implications of forest management scenarios across the four out of eight OptFor-EU Case Study Areas (CSAs). It integrates international sustainability frameworks, socio-economic indicators, Business Model Canvas (BMC) analysis, and insights from stakeholder engagement to evaluate how forest management practices (FMP) contribute to climate mitigation, ecosystem service provision, economic development, and social well-being. The BMC is specifically used to link forest management scenarios with their expected socio-economic effects, providing a structured lens for understanding impacts on value creation and stakeholder relationships.

The report begins by outlining the main socio-economic indicator families relevant to the forestry sector—economic, social, and cross-cutting environmental indicators—and introduces the methodological foundations used within OptFor-EU, including the FOREST EUROPE criteria and the Essential Forest Mitigation Indicators (EFMI) developed in D1.2. Particular focus is given to Criterion 6, which governs socio-economic sustainability, but the analysis highlights the importance of inter-criterion linkages across all six sustainability dimensions.

A detailed review of socio-economic indicators related to decarbonisation demonstrates how forests generate value through carbon sequestration, employment, ecosystem services, and circular bioeconomy pathways. The report explores how decarbonisation strategies reshape revenue models, investment needs, and social effects, supported by evidence from recent literature and global case studies.

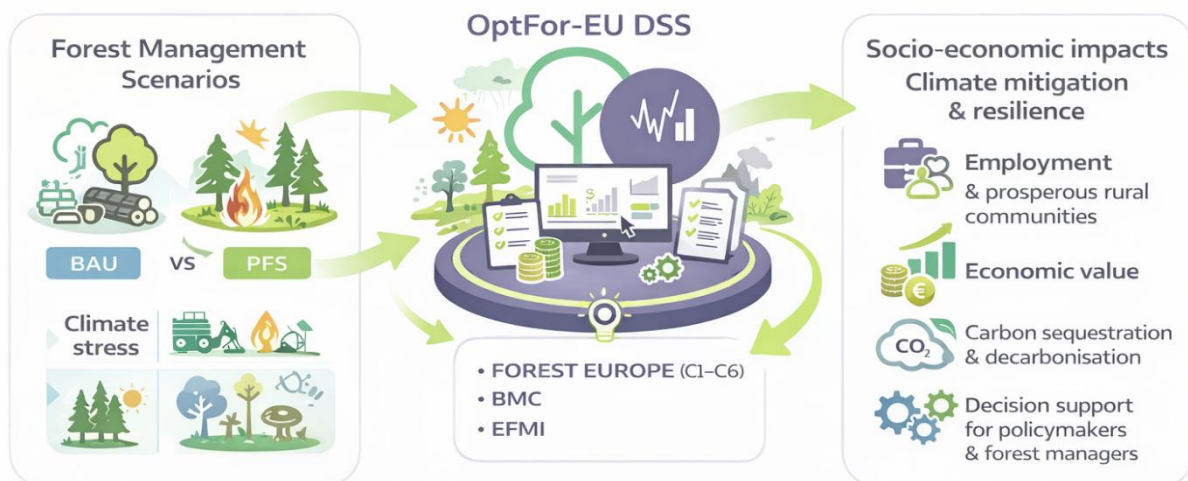
The Business Model Canvas analysis reveals the structural transformation required to move from Business as Usual (BAU) to Preferred Future Scenarios (PFS) across the 4 CSAs analysed in this deliverable (Norway, Lithuania, Romania, and Spain). While BAU models remain centred on timber production, traditional partnerships, and compliance-based governance, PFS models strategically incorporate climate services, digitalisation, diversified revenue streams (e.g., carbon credits, PES), and advanced decision-support tools such as the OptFor-EU DSS.

Case-study analyses identify common challenges—data gaps, underdeveloped social indicators, climate risks, regulatory constraints, and limited ecosystem-service monetisation—as well as opportunities for innovation, including technological solutions, stakeholder co-production, and integration of ecological–economic modelling.

Overall, D5.4 demonstrates that socio-economic performance in forestry depends on the integration of ecological resilience, value-chain diversification, and cross-sectoral governance. The results presented here directly support the development and implementation of the OptFor-EU Decision Support System by identifying the socio-economic conditions, risks, and opportunities that shape climate-resilient forestry across Europe.

Graphical Abstract

Socio-economic effects of forest management scenarios



1 Introduction

Forests play a strategic role in Europe's transition towards a climate-neutral, resilient, and bio-based economy, providing not only timber and non-wood products but also a wide range of ecosystem services that underpin economic development, social well-being, and climate mitigation. In this context, forest management decisions increasingly need to address complex trade-offs between productivity, resilience, biodiversity conservation, and socio-economic performance, under conditions of growing uncertainty driven by climate change, market volatility, and evolving policy frameworks.

Socio-economic considerations are therefore becoming a core component of sustainable forest management (SFM), alongside ecological and biophysical dimensions. Understanding how different forest management practices and planning choices affect employment, income generation, value chains, rural development, and social resilience is essential for designing management strategies that are both environmentally sound and socially acceptable. At the same time, the integration of socio-economic indicators into decision-making processes remains methodologically challenging, due to data gaps, heterogeneity across regions, and the need to align local realities with international sustainability frameworks.

Within this context, Deliverable D5.4 contributes to the OptFor-EU project by providing a structured assessment of socio-economic indicators relevant to forest management and decarbonisation pathways across selected Case Study Areas. The deliverable builds on established international frameworks and recent scientific literature, and supports the development and application of the OptFor-EU Decision Support System (DSS) by identifying key socio-economic dimensions, indicators, and methodological approaches needed to evaluate forest management scenarios in a comparable and policy-relevant manner.

The following sections introduce the main socio-economic indicator families used in the forestry sector, review their conceptual and methodological foundations, and outline the analytical frameworks adopted within OptFor-EU to support integrated, multi-criteria assessments of sustainable forest management.

1.1 Socio-economic Indicators in the Forestry Sector: Key Dimensions and Approaches

Socio-economic indicators in the forest sector are diverse and constantly evolving, reflecting the sector's multifaceted role in economic development, social well-being, and environmental stewardship (Škema et al., 2024; Riccioli et al., 2020; Imbrenda et al., 2023; Ahammad, R., & Aguilar, F. 2024).

These indicators, encompassing both economic and social dimensions, are considered essential tools for assessing the sustainability, performance, and impacts of the forest

sector. Their analysis provides insights into the effects on various stakeholders, including forest-dependent communities, forest owners, the forest workforce, recreational users, economies, and the environment.

The effective use of these metrics supports sustainable forest management (SFM) and policy development. They help policymakers, forest managers, and researchers understand the multifaceted roles forests play in livelihoods and economic health.

Ongoing methodological refinement and data integration are crucial for accurately capturing the full value and comprehensive impact of forests.

1.2 Core Types of Socio-Economic Indicators

Economic Indicators: Common measures include value added, employment, labour income, profitability, net revenue, investment, and economic multipliers. These indicators capture the direct and indirect economic contributions of forestry, such as job creation, GDP impact, and sectoral linkages (Li et al., 2019; Medvedev & Zyryanov, 2023; Salimova et al., 2022; Škema et al., 2024; Barbarese et al., 2024; Deng et al., 2023).

Social Indicators: These encompass education, employment, participation, institutional strength, demographic characteristics, and social welfare assets (e.g., recreation, tourism). Social indicators also address equity, cultural values, and the well-being of forest-dependent communities (Safe'i et al., 2024; Perkumiene et al., 2023; Pukkala, 2021; Deng et al., 2023; Ahammad & Aguilar, 2024; Andrews & Mulder, 2022; Ávila et al., 2025).

Cross-Cutting Indicators - Maintenance conservation and appropriate enouncement of biological diversity in Forest Ecosystem: While not strictly socio-economic, indicators like carbon sink, biodiversity, and ecosystem services are often integrated in socio-economic considerations to reflect the broader sustainability context (Köhl et al., 2020; Mattsson et al., 2024; Sandim et al., 2024; Deng et al., 2023; Medvedev & Zyryanov, 2023).

1.3 Methodological Approaches and Frameworks

The frameworks and methodologies for assessing socio-economic and environmental sustainability in the forest sector are fundamental for translating abstract principles of sustainable management into measurable and actionable tools. The effective adoption of socio-economic indicators requires a strong conceptual foundation supported by international standards (Forest Europe, 2020) and established national practices (Forest Europe, 2020; Pukkala, 2021). This section outlines the key methodological elements that guide socio-economic indicator selection within the OptFor-EU project.

Building on the OptFor-EU “Deliverable D1.2 – Report on a novel set of Essential Forest Mitigation Indicators” (Linser et al., 2025), it is recognized that indicators are essential not only for establishing a robust monitoring system but also for encompassing economic and social dimensions, which is crucial in the context of SFM and decarbonization actions.

In this context, three key methodological elements can be recognized: International and National Frameworks, Database and Monitoring Systems, and Multi-Criteria Decision-Making (MCDM).

In detail, **International and National Frameworks** provide guidance for selecting relevant and comparable indicators across regions. Frameworks from Forest Europe (2020), Eurostat (e.g., [specific forestry databases](#)), and the [Forest Information System for Europe](#) (FISE) managed by the EEA guide indicator selection. They ensure relevance and comparability across regions, alongside national criteria (e.g., Sweden’s Environmental Quality Objectives), which are vital for adapting international standards to national contexts and often contain subordinate indicators (Ahammad & Aguilar, 2024; Deng et al., 2023; Mattsson et al., 2024).

Regular Monitoring and Comprehensive Databases are essential for effective policy and management. **Regular, state-level monitoring** and comprehensive databases are recommended for effective policy and management, as seen in the examples of Lithuania and Italy (Škëma et al., 2024; Barbarese et al., 2024; Perkumiene et al., 2023).

Multi-Criteria Decision Making (MCDM) helps balance economic, social, and environmental indicators. MCDM is used to achieve this balance, often employing **normalization and weighting** to create **composite indices** for sustainability assessment (Pukkala, 2021; Deng et al., 2023; Medvedev & Zyryanov, 2023).

In detail, assessing sustainability in the forest sector requires the adoption of a comprehensive and balanced set of indicators that covers the three core dimensions: **economic, social, and environmental**. Table 1 provides an overview of the most relevant and commonly used indicators, highlighting their applicability across various decision-making contexts (from international and national to enterprise/farm/association level) and providing references to recent literature. These indicators are essential for continuous monitoring, performance evaluation, and supporting the strategic planning of SFM.

Table 1 - Socio-economic indicators in forestry sector in practice

Indicator Type	Example Indicators	Application Context	References
Economic	Value added, employment, profitability, Net Present Value (NPV), Internal Rate of Return	National, regional, enterprise	Li et al., 2019; Medvedev & Zyryanov, 2023; Sandim et al., 2024; Deng et al., 2023

	(IRR), Wood Harvesting, wood products, non- wood products, Wood consumption, Investments in forests and forestry, Trade in wood, Wood energy		
Social	Education, workforce, occupational safety and health, (size of) forest holdings, participation, institutional strength. Ecosystem services like recreation in forests and well-being	Community, private owners, policy	Safe'i et al., 2024; Perkumiene et al., 2023; Pukkala, 2021; Škema et al., 2024
Cross-Cutting Environmental Indicators	Carbon sink, carbon credits, ecosystem services like clean water, biodiversity credits	Sustainability, climate policy	Köhl et al., 2020; Mattsson et al., 2024; Sandim et al., 2024; Deng et al., 2023

2 Challenges and future directions within OptFor-EU

Addressing the complexity of SFM through socio-economic indicators necessitates overcoming several methodological and practical challenges. These challenges have been systematically identified within the OptFor-EU project, notably through the analysis of interviews and questionnaires conducted in WP 3 and 5.

Three main aspects were identified as challenges of the communities within the CSAs of OptFor-EU:

- **Data Gaps:** Social indicators remain underdeveloped, and regular, harmonized data collection is needed (Gough et al., 2008; Perkumiene et al., 2023; Škëma et al., 2024).
- **Integration:** Balancing economic, social, and environmental goals requires robust frameworks and stakeholder engagement (Schweier et al., 2019; Deng et al., 2023; Mattsson et al., 2024).
- **Digitalization:** Emerging technologies can enhance indicator monitoring and sector performance but require further research (Barbarese et al., 2024).

Data Gaps and Harmonization

A significant obstacle remains in the scarcity and inconsistency of available data, particularly for the social dimension of sustainability. While economic and environmental metrics often benefit from established monitoring systems, social indicators, such as those related to well-being, and participation, remain largely underdeveloped and challenging to quantify as economic indicators (Gough et al., 2008; Perkumiene et al., 2023; Škëma et al., 2024), even though there are valuable examples demonstrating how people's perceptions and lived experiences can be systematically captured and interpreted (Sanna et al., 2017; Saraev et al., 2024). Studies exploring cultural ecosystem services show, for instance, that individuals articulate the value of nature through complex and context-dependent dimensions such as indivisibility, incommensurability, and perceived naturalness, revealing interpretative repertoires that traditional, categorical ES valuation frameworks often fail to encompass (Sanna et al., 2017). For that reason, within OptFor-EU, efforts have focused on establishing regular stakeholder workshops (WP3) and direct interviews (WP3 and WP5) to ensure comparability and robust analysis regarding forest-dependent communities.

Integration and Balancing Competing Goals

Effective policy and management demand the integration of economic, social, and environmental goals. Achieving this balance, however, is a persistent challenge, often involving trade-offs that require transparent and robust decision-making frameworks

(Schweier et al., 2019). The future direction involves developing integrated modelling and assessment frameworks—such as those utilizing Multi-Criteria Decision Making (MCDM) that can weigh competing demands and provide clear recommendations. Furthermore, successful integration relies heavily on meaningful stakeholder engagement to ensure that solutions are socially acceptable and reflect the diverse values placed on forest resources (Deng et al., 2023; Mattsson et al., 2024).

To support this need, the OptFor-EU Decision Support System (DSS) is crucial, as it allows for the simulation and visualization of different scenarios, enabling decision-makers to make more informed choices by understanding the potential impacts of various management strategies.

Digitalization and Technological Advancement

Digitalization represents a crucial future direction for enhancing the efficiency and accuracy of indicator monitoring. Emerging technologies, including remote sensing, advanced geospatial analysis, and Big Data platforms, offer unprecedented opportunities to capture real-time data on forest dynamics, sector performance, and ecosystem services (Barbarese et al., 2024). These tools can significantly reduce the cost and time associated with traditional field-based monitoring. However, realizing the full potential of digitalization requires further research into developing standardized digital workflows, ensuring data interoperability, and addressing potential issues related to data access, ownership, and digital literacy within the forest sector. These aspects should not be viewed solely as technical issues: for forest owners—particularly small-scale owners—they represent significant additional costs. Sensors, data transfer, storage solutions, and analytical software or hardware entail substantial financial investments, which may limit the uptake of digital technologies despite their long-term benefits (Giannetti et al., 2023).

The OptFor-EU DSS (WP4) itself is designed to be simple and user-friendly (WP3), positioning it as a potential technological and digital advancement for the forest sector. By prioritizing ease of use, OptFor-EU aims to accelerate the adoption of complex data analysis and scenario planning tools by forest managers and policymakers.

3 The OptFor-EU Decision Support System

OptFor-EU DSS (WP4) serves as the core of the monitoring system (WP1 and WP2) but also for socio-economic analysis (WP3, WP5). The DSS goes beyond simple data collection by processing raw data to provide information on the base production indicators of the forest systems ([D1.2](#)). Crucially, the DSS integrates future scenarios ([D2.2](#) ; [D3.3](#)), enabling the analysis of potential changes that can be evaluated in economic terms([D3.2](#)). This provides policymakers with a robust basis for assessing trade-offs and guiding investment. Furthermore, the fact that the DSS incorporates indicators selected based on international frameworks (as outlined in [D1.2](#)) ensures that the results are comparable across different zones and countries, facilitating international benchmarking and policy alignment.

4 Assessment of Socio-Economic Sustainability in European Forests: Criteria within the FOREST EUROPE Framework

Forest Europe is a high-level political process that brings together European countries and the European Union to develop common strategies for the sustainable management and protection of forests. Established in 1990, it provides a platform for dialogue, policy coordination, and the adoption of voluntary commitments aimed at strengthening sustainable forest management (SFM) across Europe. Forest Europe has played a central role in defining internationally recognized criteria and indicators for SFM, supporting harmonized monitoring systems, and guiding national forest policies towards ecological, economic, and social sustainability. Its frameworks and guidelines serve as key reference points for research, policy development, and forest governance practices throughout the region.

Forest Europe utilizes a standardized framework of Criteria and indicators for Sustainable Forest Management (Linser et al, 2015), defined by six comprehensive criteria and associated 34 quantitative and 11 qualitative indicators, to evaluate the progress and status of Sustainable Forest Management (SFM) across its signatory nations (Figure 1). The socio-economic dimension of this sustainability assessment is primarily governed by Criterion 6 (C6): Maintenance of other socio-economic functions and conditions.

In detail, C6 is strategically designed to quantify and qualify the essential contribution of forests to societal welfare, and economic viability, extending beyond fundamental ecological functions. It mandates the assessment of how the value derived from the forest sector is sustained and optimized through responsible management practices. However, all the Criteria within FOREST EUROPE make a contribution in socio-economic analysis. In fact, the indicators established under Criteria C1–C5 aim to assess forest condition, productivity, biodiversity, health, and protective functions. Beyond their ecological importance, these indicators also have clear socio-economic dimensions, as they directly or indirectly affect human livelihoods, local economies, and societal well-being.

The forest indicators under the first five criteria provide a comprehensive view of both ecological and socio-economic dimensions of forest management.



Figure 1 - Overview of Forest Europe Criteria and indicators

Criterion **C1** reflects the **extent and quality of forest resources**, including forest area, growing stock, age structure, and carbon storage, and highlights how healthy and abundant forests can support timber production, non-wood products, carbon credit schemes, and eco-tourism. Policies promoting sustainable management under this criterion can stimulate investment, create employment, and enhance local economic resilience.

Criterion **C2** focuses on **forest health and vitality**, encompassing factors such as air and soil quality, defoliation, forest damage, and land degradation. Maintaining healthy forests reduces environmental risks like soil erosion, landslides, and pollution impacts, which



protects infrastructure and agricultural productivity, contributes to community safety, and supports livelihoods dependent on forest resources.

Criterion **C3** addresses the **productive functions of forests, both wood and non-wood**, including timber increments, harvests, and services. Forests provide raw materials, support small-scale enterprises, generate employment, and stabilize market opportunities. Sustainable management ensures continuous supply and diversifies income sources through non-timber products and eco-tourism services.

Criterion **C4** captures **biodiversity, measuring tree species diversity, regeneration, naturalness, genetic resources, and the presence of threatened species**. Beyond ecological significance, conserving diverse and resilient forests underpins agriculture, forestry, and tourism, attracts funding, enhances recreational opportunities, and provides a foundation for future economic and biotechnological applications.

Finally, Criterion **C5** highlights the **protective functions of forests, including soil and water conservation**. Forests that prevent erosion, floods, and landslides safeguard communities, agricultural lands, and infrastructure, reducing disaster-related costs and strengthening the resilience of both natural systems and human societies.

Overall, the forest indicators under these five criteria, not just Criterion 6, not only reflect ecological status but also provide valuable insights into socio-economic well-being. SFM ensures that forests continue to supply timber, non-timber products, ecosystem services, and protective functions, supporting both local livelihoods and broader economic stability. Recognizing the socio-economic dimensions of these indicators is essential for integrated policymaking, balancing environmental conservation with human development needs.

Taken together, these indicators illustrate that sustainable forest management is not only an environmental imperative but also a socio-economic one. Recognizing and integrating the socio-economic dimensions of forest ecosystems across Criteria 1 to 5 is essential for effective policymaking, ensuring that conservation efforts go hand in hand with human development and economic stability.

4.1 Technical Indicators for Socio-Economic SFM

The empirical evaluation of Forest Europe Criteria are all linked with socio-economic dimension and so they are executed via a suite of technically specific indicators, categorized and defined below: (Table 2)

Table 2 - Technical Indicators for the Socio-Economic Indicators of SFM

Indicator Category	Specific Indicator Focus	Analytical Relevance for SFM
Economic Structure	Forest Holdings: Number, size distribution, and the public vs. private ownership ratio.	Provides insight into land tenure patterns , fragmentation levels, and the complexity of management coordination across different ownership objectives.
	Contribution to Gross Domestic Product (GDP): Share of Value Added generated by the forestry, wood-processing, and paper industries.	Measures the macroeconomic dependence on the sector and its overall scale within national economies.
Financial Viability	Net Revenue: Profitability derived from forest management (income minus total costs).	Serves as a direct proxy for the economic sustainability and efficiency of operational forest management units.
	Investment in Forests and Forestry: Quantified public and private capital flows dedicated to resource upkeep and sectoral modernization.	Reflects the long-term financial commitment to SFM and the capacity for technological advancement and resource regeneration.
Social & Labor	Forest Sector Workforce: Employment data disaggregated by gender, activity type, and professional qualification, recreation and tourism employees	Essential for assessing the sector's role in rural development , employment quality, and the state of human capital within the industry.
	Occupational Safety and Health: Statistical rates of work-related accidents (frequency and severity) in the forestry sub-sector.	Benchmarks worker welfare and the effectiveness of safety protocols within a traditionally high-risk occupation.
Resource Utilization	Wood Consumption and Trade: Annual figures for timber imports, exports, and final consumption of derived wood products.	Tracks resource flows, market balance, and efficiency of the wood supply chain.

	Non-Wood Goods and Services (NWGS): Quantity and monetary value of non-timber products (e.g., game, resins) and services (e.g., recreation fees, certified carbon units).	Highlights the increasing economic importance of multi-functional forest management and diversification of forest outputs.
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4.2 Inter-Criteria Linkages and Holistic Assessment

While Criterion C6 provides the primary measure for socio-economic functions, SFM requires a **holistic assessment** that recognizes interdependence among all six criteria. The sustainability of socio-economic outcomes is directly contingent upon the performance measured under the other criteria.

- **Linkage to Criterion 1 (Forest Resources and Carbon):** The health, quantity, and growth rate of forest resources (C1 indicators, e.g., Growing Stock, Increment) establish the **fundamental resource base** for the socio-economic outputs measured in C6 (e.g., Contribution to GDP, Net Revenue, and Workforce). Diminution of C1 resources directly translates to reduced **economic yield and employment capacity** captured in C6.
- **Linkage to Criterion 5 (Protective Functions):** C5 assesses the forest's vital role in providing protective functions (e.g., soil conservation, water regulation, and defense against natural hazards). The provision of these functions constitutes crucial **non-market ecosystem services** that deliver significant societal benefits. Success in C5 mitigates risks and reduces costs for society and industry, thereby supporting the broader **socio-economic stability** measured in C6.
- **Systemic Feedback:** In a functional SFM system, **C6 indicators** (e.g., Investment and Net Revenue) provide the **financial capacity** necessary to implement the sustainable management measures required to achieve positive performance in **C1 (resource maintenance)**, **C4 (Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems)** and **C5 (protective function management)**. This circular relationship confirms that sustainable economic output and social welfare are essential components, not just beneficiaries, of long-term ecological stability.

This enhanced section confirms the **systemic interconnectedness** of the Forest Europe criteria, which is a key technical concept in SFM assessment.

5 Details of Socio-Economic Indicators linked with Decarbonization in the Forestry Sector: Key Insights

Decarbonization in the forestry sector is closely linked to a range of socio-economic indicators (not exclusively from Forest Europe), reflecting its potential impact on wealth, employment, and sustainable development.

Key indicators used to measure this impact include:

- Economic returns
- Poverty alleviation
- Job creation
- Valuation of ecosystem services

These indicators highlight the potential for decarbonization to drive sustainable development (see Table 2), if policies are well-integrated and systemic barriers to change are effectively addressed.

Table 3 - Table summarizing key socio-economic indicators of forestry decarbonization.

Indicator	Description & Impact	Possible Units of Measurement (Metrics)	Citations/References
Economic Returns	Decarbonization strategies can generate significant economic returns and increase national wealth, often offsetting policy costs and providing net positive fiscal impacts	Value (€/year) (e.g., Net Revenue; Net Present Value - NPV); Rate (%) (e.g., Return on Investment - ROI; Internal Rate of Return - IRR).	(Banerjee et al., 2024; Banerjee et al., 2021; Corticeiro et al., 2024).
Poverty Reduction	Implementation of decarbonization plans in forestry (e.g., Costa Rica[st2]) has been	Number (n.) (e.g., Change in number of households above poverty line); Percentage (%) (e.g.,	(Banerjee et al., 2024; Banerjee et al., 2021; Svensson et al., 2024).

	shown to lift thousands of what? out of poverty by 2050, indicating strong proper effects	Change in local Gini coefficient or income share of the poorest quintile).	
Job Creation	Decarbonization pathways often include job creation in sustainable forestry, afforestation, and value-added wood product sectors	Units (n.) (e.g., Number of Full-Time Equivalent - FTE - jobs created/retained); Rate (%) (e.g., Change in Youth Employment Rate).	(Svensson et al., 2021; Svensson et al., 2024).
Economic Growth	Decarbonization pathways often include job creation in sustainable forestry, afforestation, and value-added wood product sectors	Value (€/year) (e.g., Increase in Gross Value Added - GVA); Rate (%) (e.g., Annual sector growth rate).	(Svensson et al., 2021; Svensson et al., 2024).
Ecosystem Services Valuation	Enhanced carbon storage, water purification, and erosion mitigation are quantified as economic benefits, contributing to cumulative national wealth	Value (€/ha/year) (e.g., Monetary value of water regulation services); Volume (tCO₂/year) (e.g., Rate of Carbon sink); Score (Index) (e.g., Habitat Quality Index).	(Banerjee et al., 2024; Banerjee et al., 2021; Feitosa et al., 2023).
Forest Certification	Certification schemes improve economic performance, could increase revenue, and provide access	Area (ha) (e.g., Hectares certified under FSC®/PEFC); Percentage (%) (e.g., % of forest area certified); Value (€/m³) (e.g.,	(Corticeiro et al., 2024).

	to international markets, while also supporting social and environmental goals	Premium price paid for certified timber).	
Circular Economy & Value Chains	Transitioning to circular wood use and reverse logistics can increase[st5] climate mitigation, resource efficiency, and economic resilience, but require cross-sectoral coordination	Volume (m³/year or t/year) (e.g., Volume of secondary/recycled material used); Rate (%) (e.g., Material recycling/recovery rate); Index (Score) (e.g., Circularity Index score).	(Forster et al., 2023; Nunes, 2025).
Optimization of Chain of Custody and Transport	Improving the efficiency of logistics and transport in sustainable forest operations could reduce emissions.	Mass KgCO₂eq/unit) (e.g., Emissions per unit of wood transported); Value (€/year) (e.g., Reduction in logistics costs); Time (hours/days) (e.g., Average time for batch tracking). LCA Assessment (kgCO₂eq/unit (e.g., Carbon Footprint per m ³ of product)	(Sun & Li, 2025; Palander & Vesa, 2022)

- **Policy Integration:** Effective decarbonization requires integrated forest, environmental and economic policies that balance economic, social, and environmental objectives, including incentives for sustainable practices and support for vulnerable populations (Svensson et al., 2021; Geels et al., 2017; Svensson et al., 2024).
- **Barriers and Enablers:** Socio-economic transformation in forestry is hindered not only by fragmented value chains and limited cross-sectoral coordination, but also by insufficient digital and technical capacity, high upfront investment costs, regulatory complexity, slow adoption of innovation, the small scale and

heterogeneity of forest ownership, weak market signals for ecosystem services, and limited availability of standardized data. At the same time, transformation can be enabled by system-level visioning, organizing, and advocacy, which help align actors, foster innovation, and support coherent policy and market frameworks (Forster et al., 2023; Geels et al., 2017).

6 Developing a Business Model Canvas for Forest Decarbonization: Key Steps and Insights

Creating a business model canvas (BMC) for forest decarbonization involves adapting standard BMC elements to the unique value, stakeholders, and operational realities of carbon-focused forestry initiatives. **Successful models integrate carbon storage as a core value proposition, target both traditional and carbon credit markets, and require robust measurement and partnership strategies.**

6.1 Core Elements for a Forest Decarbonization BMC

Table 4 provides a structured overview of how the key components of the Business Model Canvas (BMC) translate into the context of forest-based decarbonization strategies. By mapping each BMC element to concrete examples from the forest sector, the table illustrates how value is created, delivered, and captured through activities such as sustainable forest management, carbon sequestration, long-lived wood products, and the substitution of energy-intensive materials like concrete or steel. This framework highlights the diversity of actors involved—ranging from CO₂-emitting companies to local communities—and the mechanisms through which forest-based solutions generate revenues, incur costs, and rely on specific resources, partnerships, and channels.

Overall, this BMC perspective provides a foundational lens for understanding how forest-related decarbonization initiatives can function as viable business models, enabling both climate mitigation and socio-economic value creation.

Table 4 - Mapping BMC elements to forest decarbonization specifics.

BMC Element	Forest Decarbonization Example	References
Value Proposition	Carbon sequestration in forests, sustainable timber production, ecosystem services provision, Long term wood products in substitution of more energy-intensive products	Setyadi et al. (2025); Reim et al. (2019); Benjaminsson et al. (2019; Pau Brunet-Navarro et al., 2021)
Customer Segments	CO ₂ -emitting companies, governments, local communities, NGOs	(Setyadi et al., 2025; Reim et al., 2019)
Channels	Voluntary carbon markets, trader networks, direct partnerships	(Setyadi et al., 2025; Reim et al., 2019)

Customer Relationships	Long-term contracts with customers and carbon market actors, combined with community engagement and certification-based assurance mechanisms.	(Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019)
Revenue Streams	Carbon credits, timber sales and consumption, payments for ecosystem services	(Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019)
Key Resources	Forest land, measurement tools, skilled labor, data systems	(Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019)
Key Activities	Sustainable forest management, Afforestation, carbon measurement, forest reporting, sustainable harvesting	(Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019)
Key Partnerships	Local governments, NGOs, certifiers, community organizations	(Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019)
Cost Structure	Land management, monitoring, certification, operational costs	(Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019)
Long live wood product		

6.2 Best Practices and Adaptations

- **Holistic Approach:** Integrate ecological, economic, and social dimensions of SFM to enhance long-term sustainability and resilience (Reim et al., 2019; Stork et al., 2023).
- **Measurement & Verification:** Invest in robust carbon measurement and reporting systems to ensure credibility and market access (Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019).
- **Stakeholder Engagement:** Involve local communities and partners to enhance legitimacy and operational success (Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019).

- **Innovative Revenue Streams:** Combine carbon credits with traditional forest products and ecosystem services (Setyadi et al., 2025; Reim et al., 2019; Benjaminsson et al., 2019).
- **Policy & Market Alignment:** Ensure continuous alignment with evolving carbon market standards and policy incentives (Gren & Zeleke, 2016; Reim et al., 2019).

In detail, the transformation of SFM requires a strategic reconfiguration of the forest sector, shifting from a traditional extraction-oriented model focused primarily on timber sales toward a value-creation model grounded in verified environmental performance. An effective BMC for forest-based decarbonization must therefore enable a deliberate, systemic redesign across all core components of the business model. This shift reframes the forest not merely as a source of wood, but as a Climate-Smart Ecosystem Services Platform capable of delivering carbon mitigation, long-lived material substitution benefits, and multiple co-benefits for society and the economy. The Value Proposition must first move beyond merely "selling wood" to embrace a dual offering: the primary value is Verified Carbon Sequestration and Climate Resilience that the forest provides as a natural, measurable solution; the sale of timber becomes a co-benefit, stemming from silvicultural activities (such as preventive thinning) that, far from being destructive, actively improve forest health and, consequently, its primary carbon-related value.

This diversification is immediately reflected in the Customer Segments, which must expand far beyond traditional sawmills. It is crucial to target Carbon Market Buyers (large corporations committed to Net Zero), who pay for emission removal or avoidance. In parallel, doors open to Public Sector Funds that issue Payments for Ecosystem Services (PES), for example, for water regulation or erosion control, and increasingly, to Financial Institutions and investors interested in Green Bonds or ESG-compliant assets, who provide capital in exchange for verifiable sustainability metrics.

To support these new value propositions, Key Activities cannot be limited to harvesting. Data-intensive activities become essential, such as Measurement, Reporting, and Verification (MRV), which includes LiDAR scans, drone surveys, and blockchain-based tracking to ensure every carbon credit sold is robust and transparent. The use of advanced modeling tools like the OptFor-EU DSS is crucial, as it allows for simulating the long-term impact of different silvicultural choices (such as Closer-to-Nature Forestry or CTNF) on carbon stock and risk mitigation (fire, drought). Adaptive and Resilience Silviculture, which includes implementing specific practices (creating firebreaks, genetic diversification), becomes a central operational activity to safeguard the asset.

Finally, success depends on abandoning the isolated forest owner model in favor of deeply integrated Key Partnerships. This includes Technology Providers (remote sensing experts and software developers like the OptFor-EU partners), Carbon Registries and Brokers who certify and place credits on the market, Forest Owner Associations or Co-ops, which are indispensable for overcoming fragmentation and achieving the necessary scale for certification, and Green Finance Entities that secure initial capital.

This complex architecture significantly boosts Business Viability because it creates Financial Resilience through multiple revenue streams (timber, carbon, PES) that insulate the model from commodity price fluctuations; it establishes Ecological Resilience by proactively reducing catastrophic risks; and, thanks to the emphasis on measurement and certification, it allows the manager to command a Premium Price for both timber and carbon assets, ensuring profitability even with higher management and planning costs.

7 Integrating Ecological and Economic Models in Forest Carbon Business Planning

Integrating ecological and economic models is essential for effective forest carbon business planning, as it enables forest managers to balance carbon sequestration, timber production, and financial outcomes while maintaining ecological sustainability. Modern approaches increasingly rely on integrated or coupled modelling frameworks—such as dynamic forest growth models linked with economic optimization models, forest sector models (e.g., EFDM, GLOBIOM), or carbon accounting tools combined with cost–benefit analysis—to capture feedbacks and trade-offs between ecological processes and economic objectives. These integrated tools allow forest managers to evaluate alternative management strategies under different policy, market, and climate scenarios, supporting more informed and forward-looking decisions.

7.1 Integration Approaches and Benefits

- **Model Coupling:** Traditionally, ecological (carbon flux in forests, forest growth, carbon sequestration in forests) and economic (market value, costs, policy) models operated separately or with limited input-output linkages. Recent research emphasizes tighter integration, where models share data, methods, and feedback loops, reducing disciplinary bias and improving projections for both carbon and economic outcomes (Fuller et al., 2025; Makar, 2019; Narayan et al., 2024).
- **Multi-Objective Optimization:** Techniques such as game theory, reinforcement learning, and multi-objective optimization allow simultaneous maximization of economic value (e.g., net present value from timber) and ecological goals (e.g., carbon storage), revealing trade-offs and Pareto-optimal solutions for stakeholders (Amiri & Limaie, 2024; Ji et al., 2024; Zhang et al., 2023).
- **Scenario and Spatial Analysis:** Integrated models often use GIS and scenario planning to assess how different management strategies affect both ecosystem services (carbon, biodiversity) and economic returns at various spatial and temporal scales (Bottalico et al., 2016; Verma et al., 2023; Mao, 2022).
- **Policy and Market Alignment:** Assigning economic value to carbon (e.g., carbon pricing) within integrated models can shift optimal management strategies toward greater carbon retention, forest management strategies toward greater carbon retention, understood as the maintenance of higher forest carbon stocks, thereby influencing harvest timing, intensity, and land-use decisions (Parkatti et al., 2024; Narayan et al., 2024).

7.2 Key Insights from Recent Research

The integration of ecological, economic, and spatial modelling approaches is central to assessing forest-based decarbonization pathways and supporting robust forest management decisions. Different integration methods offer distinct analytical strengths—ranging from reducing modelling bias to identifying trade-offs, incorporating spatial dynamics, and capturing the effects of carbon pricing on management strategies. The table below summarizes key integration methods commonly applied in forest and climate-related analyses, highlighting their primary outcomes and associated references (Table 5). Together, these methods illustrate the diversity of tools available to support comprehensive, multi-dimensional evaluation of forest management scenarios.

Table 5 - Integration methods and their benefits.

Integration Method	Key Outcomes/Benefits	References
Iterative model sharing	Reduces bias, improves policy relevance	(Fuller et al., 2025; Makar, 2019; Narayan et al., 2024)
Multi-objective/ game theory	Identifies trade-offs, supports stakeholder negotiation	(Amiri & Limaie, 2024; Zhang et al., 2023)
GIS & scenario modeling	Visualizes spatial trade-offs, supports regional planning	(Bottalico et al., 2016; Verma et al., 2023; Mao, 2022)
Carbon pricing in models	Incentivizes carbon storage, alters economic decisions	(Parkatti et al., 2024; Narayan et al., 2024)

Integrating ecological and economic models in forest carbon business planning enables more accurate, relevant, and sustainable decision-making by capturing complex interactions and trade-offs between environmental and financial objectives. This approach supports adaptive management, stakeholder engagement, and policy alignment for long-term forest and climate benefits.

8 Case study areas

The eight OptFor-EU Case Study Areas (CSAs) (Figure 1) constitute the empirical foundation for applying and operationalising the socio-economic indicators developed in this Deliverable. While the indicators capture economic performance, social well-being, and ecosystem-service provision at conceptual and methodological levels, their **practical relevance** can only be understood when examined in real forest landscapes with different management systems, ownership structures, ecological conditions, and socio-economic contexts.

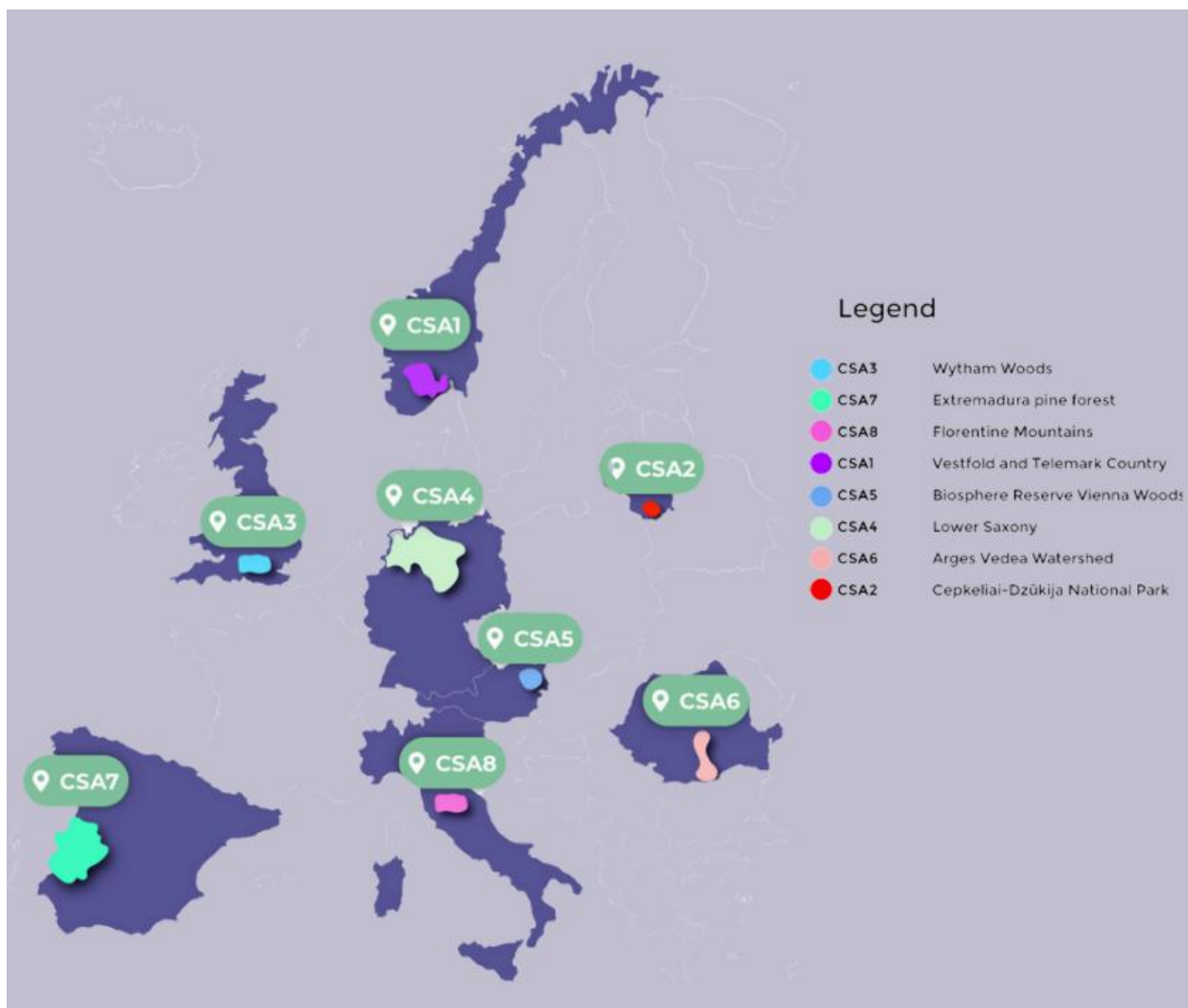


Figure 1 – Location of 8 CSA of the OptFor-EU project

Building on the detailed CSA characterisation already presented in [D2.1](#) and [D3.2](#), this section introduces the specific features of each study area that are most relevant for interpreting socio-economic effects of forest management scenarios. The CSAs represent a wide spectrum of European forestry—from intensively managed production forests to conservation-oriented landscapes, from Mediterranean agro-forestry systems to boreal

and alpine environments. This diversity is essential for understanding how socio-economic indicators perform across contrasting ecological zones, governance models, and cultural settings.

Furthermore, the CSA descriptions serve as the **contextual anchor** for the subsequent analysis. They explain the local realities—such as forest ownership patterns, management intensity, environmental constraints, community dependence, and multifunctional expectations—that directly shape how indicators such as employment, value added, profitability, recreation, cultural services, investment needs, and wood-based value chains should be interpreted.

In the following analyses, the socio-economic indicators will be connected to these CSA-specific conditions to illustrate how forest management scenarios influence both economic outcomes and social dimensions of sustainability. This enables a **comparative, multi-scalar assessment** that reflects real-world variability rather than theoretical assumptions.

The next sub-chapters present a brief description of the eight CSAs.

8.1 Norway

The CSA covers 1.6 million hectares, of which 64% (about 1.02 million ha) is forested, consisting mainly of Boreal (EFT1) and Hemiboreal/Nemoral coniferous–mixed (EFT2) forest types. In 2021, approximately 1.26 million m³ of timber were harvested, while around three million trees were planted over 10,000 hectares, representing 1.4% of the forest area. The annual harvest corresponds to about 0.6% of the forest. Ownership is mixed, including both private and state holdings, with roughly 10,000 forest owners and three major private estates—Cappelen, Fritzøe, and Løvenskiold-Fossum. Forest management is challenged by the high complexity of regulatory compliance and increasing operational costs, contributing to significant economic vulnerability. Policy instruments strongly influence management decisions, and stakeholders increasingly prioritize forest services beyond timber production, such as recreational and cultural values.

8.2 Lithuania

The forest covers 1,000 km² and includes several major ecosystem functional types, primarily hemiboreal mixed forests (EFT 2), mesophytic deciduous stands (EFT 5), and extensive wetland and floodplain forests (EFT 11–12). Approximately 87 % of the area consists of productive forest land managed mainly for commercial timber and pulpwood production. Management follows conventional rotation forestry with rotation periods of about 70–100 years, and harvested stands are consistently reforested to maintain long-term productivity.

Ownership is divided between state and private forest holders, with active involvement of private forest owners' associations in management decisions and coordination. Beyond timber production, the area supports growing public interest in non-timber forest products such as mushrooms, as well as recreational use.

From an environmental perspective, around 18 % of the forest area is classified as strictly protected ("group 1"), contributing to biodiversity conservation. Dominant tree species across the landscape include *Pinus sylvestris*, *Picea abies*, *Betula pendula*, and *Alnus glutinosa*. High groundwater levels and the presence of floodplain ecosystems strongly influence management intensity, requiring careful consideration of hydrology, soil sensitivity, and ecological values.

8.3 United Kingdom

Wytham Woods in Oxfordshire covers a relatively small area of about 4 km² and represents an ancient semi-natural woodland dominated by mesophytic deciduous forest (EFT 5). Unlike commercially managed forests, Wytham is used primarily for ecological research and conservation, with only minimal commercial activity.

The woodland is owned and managed by the University of Oxford, which maintains a long tradition of public access and supports extensive citizen-science initiatives. Historically, the site was managed as "coppice with standards," a practice that has contributed to its structural complexity.

Today, Wytham Woods is classified as a "minimum intervention" or ancient semi-natural woodland area. It hosts high structural diversity, substantial deadwood volumes, and a mixture of characteristic broadleaf species such as *Quercus robur*, *Fraxinus excelsior*, and *Acer pseudoplatanus*. These features make it one of the UK's most important long-term ecological research sites.

8.4 Germany

The region covers a total area of 4.76 million hectares, of which roughly 25 %—around 1.2 million hectares—is forested. The dominant forest types include hemiboreal and mixed forests (EFT 2) as well as deciduous and beech-dominated types (EFT 5–7). These forests are highly productive, with rotation ages typically ranging from 80 to 120 years, and they support a variety of commercially important species such as *Picea abies*, *Fagus sylvatica*, and *Pinus sylvestris*.

Ownership is mixed, though state forests account for a larger share than privately owned areas. Management across the region generally follows national sustainability standards and is certified under schemes such as PEFC and FSC®. Social expectations toward forest

multifunctionality and responsible stewardship play a significant role in shaping management decisions.

In recent years, environmental priorities have become increasingly prominent. Natural regeneration and the promotion of mixed-species stands are gaining importance, partly in response to storm damage and bark-beetle outbreaks that have affected large areas. Biodiversity enhancement, resilience-building, and the diversification of forest structure are now central themes in ongoing forest policy and practice.

8.5 Austria

The Austrian CSA5 region covers approximately 1,000 km² and is dominated by mesophytic and beech forest types (EFT 5, 6, and 7). Around 24 % of the area is left unmanaged, contributing to natural forest dynamics and biodiversity conservation.

Forest management in the region focuses on high-quality sawlog production while also supporting multifunctional uses. Rotation periods typically range from 80 to 120 years, depending on production goal and species. The forest sector is largely shaped by family-owned properties, which are characteristic of Austria's forestry structure. Large forest owners in this region are the Austrian Federal Forests and the City of Vienna. National forest law ensures that harvested areas are promptly reforested and that soil protection measures are upheld.

Environmentally, the region contains extensive beech and oak-dominated forests. Large parts of the case study area are within the NATURA 2000 network, providing additional protection for habitats and species of European importance, but allow SFM.

8.6 Romania

The Romanian CSA6 region encompasses approximately 18,000 km², featuring a diverse range of forest types including alpine (EFT 3), mesophytic and beech-dominated (EFT 5 and 7), as well as floodplain and wetland forests (EFT 14). Located in the Carpathian Mountains, the area exhibits a strong altitudinal gradient that shapes species composition, structure, and management practices.

Timber extraction plays an important economic role, with selective logging commonly practiced in mountain zones to balance productivity and ecological considerations. Ownership is mixed, with both state and private holdings, and forest restitution processes continue to influence management. Local communities rely heavily on these forests for rural livelihoods, including fuelwood collection and grazing.



Approximately 25 % of the forest area is unmanaged, while only around 1 % represents old-growth forest. The region is of high environmental significance, hosting rich carbon stocks and biodiversity, particularly in beech-fir-spruce mixtures that are characteristic of the Carpathian ecosystem.

8.7 Spain

The Spanish CSA7 region in Extremadura, covers approximately 690 km² and is characterized by broadleaf evergreen and Mediterranean coniferous forests (EFT 9–10). Forest management is focused on traditional systems such as dehesa and pine forests, supporting multiple uses including cork production, firewood collection, and grazing. Although timber productivity is relatively low, the area holds high multifunctional value.

The forests form part of an agro-forestry system that provides important employment opportunities in rural communities. About 12 % of the area is left unmanaged, contributing to natural dynamics and habitat diversity. Environmental management emphasizes drought resilience, fire prevention, and soil conservation, reflecting the sensitivity of Mediterranean ecosystems to climate stress.

8.8 Italy

The Italian CSA8 region in Tuscany, encompassing the Vallombrosa and Sant'Antonio Forests, covers approximately 800 km² and includes forest types ranging from deciduous to Mediterranean (EFT 5–8). The landscape comprises a mixture of managed forests and strictly protected reserves, reflecting a balance between sustainable use and conservation priorities.

Timber extraction is limited, with management plans primarily emphasizing ecological conservation. Governance is shared between the regional forest authority and local cooperatives, supporting both sustainable management and community engagement.

About 25 % of the forest area is left unmanaged, while roughly 1 % consists of old-growth stands. Environmental management actively promotes biodiversity through measures such as increasing deadwood volumes. Typical species include *Fagus sylvatica*, *Abies alba*, various *Quercus* species, *Castanea*, and *Pinus* species, representing the ecological richness and diversity of the region.

9 Methodology

The methodological approach (Figure xxx) adopted in this Deliverable reflects the current stage of data availability within the project. Since the modelling outputs of WP2—essential for conducting a full quantitative trade-off assessment—are not yet complete, this Deliverable does not provide a comprehensive analysis of trade-offs across management scenarios. Instead, it builds on the information presently available from three sources:

1. The BAU descriptions and contextual data provided by WP2,
2. The stakeholder inputs collected through WP3, and WP5
3. The socio-economic perspectives and preliminary analyses developed in WP5.

Based on these inputs, stakeholders in each CSA independently developed two BMC representations: one describing the current BAU model and one describing the PMS emerging from their priorities, perceptions, and local knowledge. These stakeholder-generated BMCs reflect real practices, expectations, challenges, and opportunities as experienced on the ground, making them a crucial qualitative foundation for the socio-economic assessment.

For each CSA, the two BMCs (BAU and PMS) were systematically compared across all components—value proposition, customer segments, key activities, revenue streams, cost structure, partnerships, and others. This comparison enabled the identification of differences, gaps, and necessary improvements to move from BAU toward a more climate-smart, ecosystem-service-oriented management model (PMS).

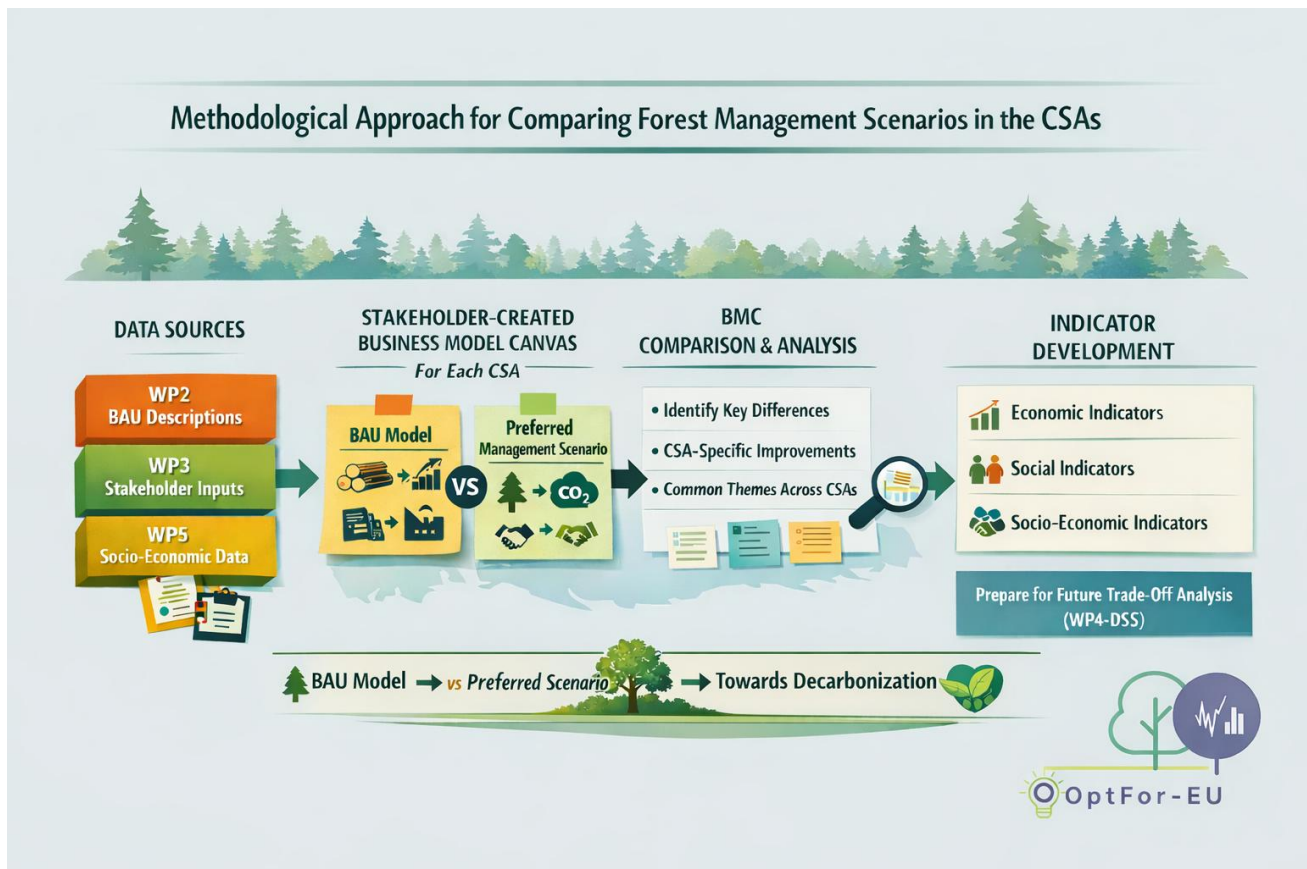


Figure 2 - Methodological workflow for comparing forest management scenarios across the CSAs. The infographic illustrates how BAU and Preferred Management Scenario Business Model Canvas (BMC) representations—developed directly by CSA stakeholders—are compared to identify differences, improvement needs, and common themes. These insights form the basis for preliminary economic, social, and socio-economic indicators and support the transition towards forest-sector decarbonization

A cross-CSA synthesis was then conducted to detect shared patterns and common transformation needs across Europe’s diverse forest contexts. Finally, these findings informed a preliminary list of economic, social, and combined socio-economic indicators, which may be used in the future trade-off analysis once WP2 modelling outputs are fully implemented within WP4’s decision support system (DSS).

This methodological process provides the foundation for understanding the socio-economic implications of management change and for supporting the development of integrated, climate-smart forest management strategies.

10 Business Model Canvas Analysis

The BMC framework is used to map the evolution of forest management across the CSAs. To comprehensively understand the pathway required to achieve climate and economic sustainability, two different timeframe models have been developed and compared by CSA.

The Business as Usual (BAU) Scenario serves as our baseline, meticulously detailing the current, traditional business model for forest management within each CSA. This scenario documents the existing revenue streams, primary cost structures, key partners, and, critically, the structural vulnerabilities that plague the sector.

The Preferred Future Scenario outlines the optimal, resilient business model that each CSA aspires to implement, fully integrating the goals of Climate-Smart Forestry and leveraging the outcomes of the OptFor-EU project. This model necessitates a profound transformation, strategically focusing on: Diversified Value Propositions, including the monetization of Ecosystem Services (PES) and Carbon as primary revenue sources; Key Activities and Resources, prioritizing the maximal adoption of the OptFor-EU Decision Support System (DSS) for planning and risk management; and Strategic Partnerships, involving the active collaboration of the entire value chain, organized forest owners, and climate finance institutions.

Crucially, it must be noted that each CSA (e.g., Norway, Lithuania, Romania, and Spain) has independently completed its own distinct BMC for both the current scenario and the preferred future scenario. This localized methodology ensures the analysis is contextualized and remains actionable, providing a clear, customized roadmap for transitioning from the present state to the desired future state within each region.

10.1 Norway Business as Usual vs. Preferred Future Scenario comparison

NORWAY - BUSINESS MODEL CANVAS – BUSINESS AS USUAL

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom -up participatory approach, ensuring the indicators are feasible,



Partners	Activities	Value Proposition	Relationships	Customers
- Individual forest owners (small, one-man or one-family companies, forestry as part-time income) - large professional forest owners, - forest owner associations - authorities (state ombudsman, municipalities) - research institutions - wood transport companies - logging companies - sawmills and other industrial buyers.	Thinning, planting, lumber road creation and maintenance, timber harvesting, compliance.	- Reliable timber supply - sustainable forestry practices through PEFC certification. - Coordinated action through forest owner associations.	Associations manage buyer relations for small companies. Mostly long-term frameworks and contracts and structured sales within the long-term framework. Large companies do the same, but as part of internal supply-chain management in the industrial group they belong to.	Local sawmills, cellulose industry, other wood-dependent industries, export markets (Sweden, Germany).
Threats/ Risks	Resources	Costs	Channels	Revenues
- Wildfire: partial or major damage possible in dry years. Increasing risk - Windthrow: Increased frequency of high wind, latest storm «Amy», which led to massive damage in south-Eastern Norway. - Insects/Pathogens: bark beetle attacks have been reported to be increasing. - Snow breakage: Heavy snowfalls and increased number of days with temperatures just above and below 0 Celsius increases this threat. - Political change: Different parties have very different attitudes to forest management and especially biodiversity.	- Small forest owners: Forest land (small plots), farms, fields, basic machinery (tractors), logging roads. Human resources: creativity (multi-tasking: farming, harvesting, tourism), family labor, locally sourced workers, collaboration and community spirit. - Large forest owners: Forest land (large plots), industrial facilities, land for development, tourism facilities, logging roads (vast network), forest machinery. Human resources: professional forest managers, logistics specialists, industrial competence (processing), sales and marketing, real estate development, professional staff and management functions, access to a large network of entrepreneurs.	- Labor and equipment costs, planting and thinning, administration costs to forest owner associations, property taxes. - For large forest owners also industrial costs, wages, transport and logistics, capital and real estate costs.	- Local forest owner associations coordinate harvesting and sales between individual small foresters. Their customers are typically local sawmills or industrial groups. - Large companies sell directly, usually to companies within the same industrial group or for export	- Small forest owners: Timber sales make up less than 50% of income. Other sources include farming, hunting and fishing rights, tourism (cabins, guided tours), subsidies, timber for wood burning, and external income from regular jobs. - Large forest owners: Timber sales, timber industry operations, property development, hunting and fishing rights, energy production (solar, wind, hydro, bioenergy).

NORWAY - BUSINESS MODEL CANVAS – PREFERRED FUTURE SCENARIO

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom-up participatory approach, ensuring the indicators are feasible,

Partners	Activities	Value Proposition	Relationships	Customers
In addition to BAU partners, also public authorities (regulatory framework, financial incentives, project funding), tech and innovation companies (develop tools such as DSS, drone surveillance, AI for analysis, biochemical innovations for timber use), construction industry (replace concrete with timber), energy companies (bioenergy and CCS), financial institutions (financing the decarbonisation transition). Forest owner associations would have a central role in coordinating these efforts.	- Advanced forest management for carbon sequestration (precision planting, new wood types, more intensive thinning and nursing, longer growth cycles to increase carbon uptake, systems for verifying carbon storage for carbon credits). - Expanded industrial processing (more timber for construction and long-lived products, less for paper, biochemical processing for biofuel, bioenergy facilities with CCS). Integrated supply chain and logistics optimization (electric/hydrogen-powered machines and transport, digital tracing for LCA). New business models (sale of carbon credits, increased timber use in construction).	- Direct carbon sequestration and storage in standing forest and long-life products (buildings, furniture). - Replacement of fossil materials in construction and bioenergy. - Bioeconomic development (biofuel, biochemicals, textiles). - Biodiversity and ecosystem services (if regulation and incentives allow). - Overall: An integrated approach focusing on traceability, documented climate benefits, collaboration, and innovation to appeal to a new customer base of environmentally conscious buyers and carbon credit purchasers.	Strategic partnerships, consulting services for decarbonisation, value-based relationships, digital and data-driven relations to ensure transparency and increase automation of value chains.	- Construction and energy companies - Companies with emission obligations - Chemical and advanced materials companies - Public sector (if sustainability purchase policies are implemented)
Threats/ Risks	Resources	Costs	Channels	Revenues
- Capital investments in new infrastructure failing to materialize. - Technology and digitalisation could become too expensive for small forest owners. - Stalling R&D in biochemical products, CCS and process optimisation. - Recruitment of staff, access to competences. - Ecosystem services may suffer if carbon sequestration becomes the most important goal. - Political threats: funding/priorities can change, green washing, regulatory complexity.	- Physical resources: Optimized forests through better management practices, bioraffineries for bio-products, carbon capture and storage infrastructure (e.g., Longship project), upgraded sawmills for solid wood construction materials, renewable energy infrastructure. - Technological resources: Precision forest management tech (DSS, drones, satellite, LIDAR, AI analytics), digital traceability systems, LCA software for lifecycle carbon footprint documentation, industrial biotech facilities. - Human resources: Climate and ecology experts, data analysts, process and biochemical engineers, sales & marketing, lobbying.	Capital investments in new infrastructure, technology and digitalisation, research and development, education, training and upskilling, certification costs.	Transparent and digitally traceable systems, partnerships and strategic alliances with buyers, sale of verifiable services (carbon credits and negative emissions as a service), active branding and communication of 'Norwegian climate-friendly forestry'.	Sale of carbon credits, sale of biodiversity and ecosystem services, biofuels and biochemicals, increased revenue from higher quality timber, increased revenue from tourism services.

The following paragraphs present a comparison between the BAU and the PFS for Case Study Area 1 (Norway), based on the BMC framework and drawing on the references and inputs provided by the CSA leaders.

Key Partners

In the BAU context, partnerships are mainly rooted in the traditional forestry sector. Individual forest owners, often small family-based enterprises, operate alongside large professional owners, forest owner associations, wood transport companies, logging operators, sawmills, and industrial buyers. Authorities and research institutions also play a role, primarily to provide regulatory oversight and technical knowledge. This structure reflects a conventional and relatively compartmentalised value chain, where collaboration mostly aligns with timber production and sales.

The Preferred Future Scenario (PFS) expands this network significantly. In addition to BAU partners, public authorities become more deeply involved by providing incentives and regulatory alignment for decarbonisation efforts. Technology and innovation companies are added to support advanced forest-management tools, AI analytics, drone surveillance, and DSS development. The construction industry becomes a strategic partner—reflecting increased demand for timber substitution in buildings—while energy companies contribute to bioenergy production and carbon capture. Financial institutions also emerge as key actors, providing capital for low-carbon transitions. Forest owner associations still play a central role, but now coordinating multi-sectoral innovation instead of merely mediating timber sales.

Overall, the PFS represents a shift from a conventional forest-value chain to a broad climate- and innovation-driven ecosystem, with new partners enabling enhanced technological, financial and environmental performance.

Key Activities

BAU activities are centered on fundamental silvicultural operations: thinning, planting, road maintenance, timber harvesting and ensuring legal compliance. These activities reflect a system in which forest management focuses on timber production, routine maintenance and regulatory requirements, with limited emphasis on climate mitigation or advanced value creation.

The PFS, by contrast, transitions toward sophisticated forest-based climate solutions. Activities expand to include precision planting, use of new wood types, longer growth cycles to enhance carbon sequestration, and the establishment of verification systems for carbon storage. Industrial processing evolves toward high-value timber for construction and biochemical products, reducing reliance on pulp or short-lived goods. The supply chain becomes digitised and optimised through traceability, electric or hydrogen-powered machinery, and LCA-based carbon accounting. Moreover, entirely new business



models emerge—carbon credit generation, carbon-negative bioenergy, and increased use of circular and bio-based materials.

Overall, while BAU activities ensure forest productivity, PFS activities reposition the CSA as a key player in Norway's decarbonisation agenda and circular bioeconomy.

Key Resources

In the BAU scenario, resource availability differs notably between small and large forest owners. Small owners rely on small plots, basic machinery, family labour and community solidarity, supported by simple forest-road networks. Large owners, on the other hand, have industrial facilities, advanced machinery, larger land areas and specialised professional staff. Together, these resources support traditional forestry and timber-production systems, but with wide disparities in capacity.

The PFS introduces a far more advanced and integrated resource base. Physical resources include upgraded forests, modern sawmills, bioraffineries, and CCS infrastructure. Technological resources expand to cover precision forestry tools (LIDAR, AI, drones), digitalised logistics, traceability systems, and LCA software. Human resources also shift toward specialised expertise in climate ecology, biochemistry, digital analysis, marketing, and regulatory engagement. Such resources reflect a high-tech, bioeconomy-oriented sector requiring continuous innovation and strong professional competencies.

Overall, PFS upgrades the resource portfolio from operational and sometimes rudimentary (for small owners) to technology-, data- and climate-innovation intensive systems.

Value Proposition

The BAU value proposition is primarily based on reliable timber supply and PEFC-certified sustainable practices. Coordination through associations helps small owners access markets and maintain stable relationships. This model meets traditional industrial demand and local economic needs but remains tied to timber as the dominant product.

The PFS extends the value proposition dramatically. Forests become providers of multiple climate benefits: carbon sequestration in standing biomass and long-lived products, substitution of fossil-intensive materials in construction, renewable bioenergy, and biochemical feedstocks. Additionally, biodiversity and ecosystem services may be captured as marketable values if regulation permits. The proposition emphasises traceability, transparency, and scientifically verified climate impacts, appealing to a new customer base that prioritises climate accounting and decarbonisation outcomes.

Overall, while BAU offers continuity and security in timber supply, PFS transforms forests into multifunctional climate infrastructure supporting Norway's transition to a low-carbon, bio-based economy.

Customer Relationships

BAU relationships are often mediated by associations for small owners and through internal industrial frameworks for large owners. These connections are relatively stable, built around long-term contracts and established supply-chain agreements focused on timber delivery.

In the PFS, customer relationships evolve toward strategic, value-driven partnerships. Consulting services for decarbonisation, digital transparency, automated value chain integration, and life-cycle documentation create deeper, more data-intensive relationships. Trust and engagement shift from contractual reliability to analytical credibility, verified climate benefits, and ongoing technical collaboration.

Overall, PFS introduces a more sophisticated, service-based relationship model, expanding from traditional commodity transactions to long-term climate-service partnerships.

Channels

Under BAU, channels remain conventional: forest owner associations coordinate sales between small owners and local sawmills; large companies sell directly to industrial groups or export markets. The chain is efficient but traditional.

The PFS adds modern, digital and service-based channels: traceable digital platforms, transparent carbon-accounting tools, strategic alliances with climate-conscious buyers, and active branding around “Norwegian climate-friendly forestry.” New channels also include the sale of verifiable climate services like carbon credits and negative-emissions products.

Overall, channels evolve from localised timber-market structures to digitalised, transparent, climate-centric market systems with global reach.

Customer Segments

BAU customers are primarily wood-dependent industries: sawmills, cellulose producers, other manufacturers, and export markets (e.g., Sweden, Germany). The customer base is sector-specific and tied to the timber-production chain.

In the PFS, customer segments broaden significantly. Construction companies seeking fossil-free materials, energy firms aiming for bioenergy or CCS, companies with emission obligations, chemical/materials producers, and even the public sector (if procurement regulations favour sustainability) become part of the market. The inclusion of organisations with climate obligations transforms the CSA’s forest resources into assets that meet growing regulatory and ESG demands.

Overall, PFS increases market diversity, resilience and value, tapping into high-growth sectors of the low-carbon economy.



Cost Structure

The BAU cost structure includes labour, equipment, planting, thinning, association-related administrative expenses, and taxes. For large owners, additional industrial, logistics and capital costs are significant but typical of established forestry operations.

Under the PFS, costs expand to fund transformative technological and infrastructural investments. These include digitisation, R&D, new machinery, bioenergy and CCS infrastructure, and continuous training and upskilling. Certification becomes more complex and more frequent, reflecting increased requirements for climate documentation.

Overall, PFS costs are higher and more innovation-driven but are essential for unlocking new revenue streams and climate advantages.

Revenue Streams

BAU revenues come predominantly from timber sales, although small owners diversify through farming, tourism, hunting rights and external employment. Large owners expand income via energy, property development and industrial operations. Still, timber remains the backbone.

In the PFS, revenue diversification becomes central. New income is generated from carbon credits, biodiversity services, biofuels, biochemicals, and higher-value timber products. Tourism and recreational services increase, benefiting from improved environmental and climate branding. This introduces resilience by decoupling income from timber markets.

Overall, the PFS revenue model is more diversified, scalable and aligned with emerging climate and bioeconomy markets.

Threats and Risks

BAU risks revolve around natural disturbances—wildfire, windthrow, insect attacks, snow damage—as well as political shifts affecting biodiversity regulation. These risks reflect climate change impacts and policy fluctuations affecting forest operations.

The PFS introduces additional systemic risks: failure to secure necessary capital, unequal access to technology for small owners, stalled R&D in biochemicals and CCS, skills shortages, and regulatory complexity. There is also the risk that prioritising carbon sequestration could compromise biodiversity if not managed carefully.

Overall, while BAU risks are environmental and regulatory, PFS risks combine environmental, financial, technological and socio-political dimensions, requiring more sophisticated management strategies.

Synthesis: Main Improvement Opportunities

1. **Support small forest owners in the transition** through investment schemes, shared digital platforms and technology cooperatives.
2. **Enhance the integration of digital traceability and LCA tools** to strengthen credibility and market access for climate-oriented products.
3. **Expand bioeconomy infrastructure** such as bioraffineries and solid-wood construction facilities.
4. **Develop a coordinated national carbon-verification system** to create a stable and transparent carbon-credit market.
5. **Promote workforce development**, including training in digital tools, biochemistry, and climate reporting.
6. **Strengthen biodiversity safeguards** to balance carbon sequestration objectives.
7. **Scale up collaborative innovation between forest owners, tech companies and construction actors** to maximise decarbonisation impact.

10.2 Lithuania Business as Usual vs. Preferred Future Scenario Comparison

LITHUANIA - BUSINESS MODEL CANVAS – BUSINESS AS USUAL

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom-up participatory approach, ensuring the indicators are feasible,



Partners	Activities	Value Proposition	Relationships	Customers
- Universities and research centres - Local and National authorities, protected areas administrations - Forest companies and individual owners - Local conservation NGOs and community groups	- Forest cutting: main cuttings (selective, occasional and clearcuts), silvicultural (educational) cuttings, sanitary cuttings, and reforestation - Standard monitoring - Regulatory compliance - Forest Inventory, management and planning - Management simulations and scenario analysis (via DSS)	- Sustainable wood production within protected area rules - Nature protection, allowance for limited community use - Valuation of ecosystem services - Use of the OptFor-EU DSS to estimate indicators and management scenarios (carbon, wildfire risk, biodiversity, available timber, etc.)	- Regular consultation with local stakeholders - Community education programs and workshops - Limited continuous technical support - Customized DSS-based services (tailored management scenarios) - Community network among different CSAs	- CSA Forest Managers, Protected areas managers and government agencies - Public administrations and policy makers - Local communities and land users - Universities and research centres - Private and public forest owners focused on timber income - Timber industries and cooperatives
Threats/ Risks	Resources	Costs	Channels	Revenues
- Climate extremes (drought, fire, pest outbreaks) - Conflicting interests on land use or adaptive management - Funding shortfalls for long-term monitoring/restoration - Invasive species or habitat degradation - Changes in management - Funding dependant on traditional sources - Loss of timber revenue	OptFor-EU DSS platform for management simulations and indicators - Monitoring data (UAV, inventories) - Scientific expertise (silviculture, modelling, ecosystem services) - Network of institutional and private partners	- Monitoring and data collection - Use and integration of the OptFor-EU DSS - Certification and verification costs - Forest management planning - Maintaining Standards - Cutting and reforestation within legal requirements	- Digital platforms (including the OptFor-EU DSS) - Workshops and training sessions, community meetings - Cooperation networks (universities, forest owners and managers, local authorities) - ESG reports and environmental storytelling	- Analytical and scenario-based services via OptFor-EU DSS - Public funding (RDP, Horizon Europe, LIFE) - Partnerships with private companies - Consultancy Fees

LITHUANIA - BUSINESS MODEL CANVAS –PREFERRED FUTURE SCENARIO

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom-up participatory approach, ensuring the indicators are feasible,

Partners	Activities	Value Proposition	Relationships	Customers
- Universities and research centres - Local and National authorities, protected areas administrations - Forest companies and individual owners - Local conservation NGOs and community groups	- Adaptive forest (restoration, thinning, native species planting) - Hydrological monitoring and fire risk reduction - Scientific research and biodiversity assessments, including ecosystem services - Stakeholder engagement, education, training, and participatory monitoring - Downscaled climate-scenario modelling for RCP 2.6	- Enhanced ecosystem climate resilience and carbon storage - Quantification and valuation of ecosystem services - Model for climate-smart forestry in protected areas - Opportunities for learning, recreation, and science - Use of the OptFor-EU DSS to estimate indicators and management scenarios (carbon, wildfire risk, biodiversity, available timber, etc.). - Decision support that integrates climate mitigation and adaptation and economic returns - Data for climate/ESG reporting	- Co-development based on regular consultation with local stakeholders - Community education programs and workshops - Continuous technical support - Customized DSS-based services (tailored management scenarios) - Community network among different CSAs but also with climate corporative landscape and public clients.	- CSA Forest Managers, Protected areas managers and government agencies - Public administrations and policy makers - Local communities and land users - Universities and research centres - Climate-finance institutions, green investment funds - National GHG inventory agencies and climate ministries
Threats/ Risks	Resources	Costs	Channels	Revenues
- Climate extremes (drought, fire, pest outbreaks) - Conflicting interests on land use or adaptive management - Funding shortfalls for long-term monitoring/restoration - Invasive species or habitat degradation - Changes in management	- OptFor-EU DSS platform for management simulations and indicators - Monitoring data (UAV, TLS, inventories) - Scientific expertise (silviculture, modeling) - Network of institutional and private partners - Downscaled RCP 2.6 climate data	- Monitoring and data collection - Use and integration of the OptFor-EU DSS - regular model updates to latest climate science & policy - Certification and verification - Personnel and training - Community engagement and education program - Communication, outreach, and data management	- Digital platforms (including the OptFor-EU DSS) - Workshops and training sessions, community meetings - Cooperation networks (universities, forest owners and managers, local authorities) - GHG inventory systems, Climate Reports, ESG reports - Scientific events (e.g., conference on climate change)	- Analytical and scenario-based services via OptFor-EU DSS including data and access subscription - Public funding (RDP, Horizon Europe, LIFE) - Partnerships with private companies

The following paragraphs present a comparison between the BAU and the PFS for Case Study Area 2 (Lithuania), based on the BMC framework and drawing on the references and inputs provided by the CSA leaders.

Key Partners

In the Business as Usual (BAU) configuration, partnerships are primarily anchored within the traditional forestry and conservation landscape: universities, research centers, protected-area administrations, forest companies, and NGOs. These partners ensure regulatory compliance, operational forest management, and basic scientific support.

In the Preferred Future Scenario (PFS), this partnership base is retained but strategically expanded to include climate-finance institutions, national GHG inventory agencies, and climate ministries. This shift indicates a transition from a forest-sector-bounded network toward a multi-level climate governance and finance ecosystem. Such expansion aligns the CSA with emerging climate-mitigation mechanisms, enhances political relevance, and opens doors to diversified long-term funding streams.

Overall, the PFS demonstrates a more future-proof, financially resilient partnership structure with stronger integration into climate policy and ESG frameworks.

Key Activities

Under BAU, activities revolve around conventional forestry operations—such as selective cutting, reforestation, sanitary interventions—and core monitoring tasks. Planning, regulatory compliance, and scenario analysis via the OptFor-EU DSS support operational decision-making but remain within the logic of traditional forest management.

In contrast, the PFS reframes activities around climate-smart, ecosystem-based forestry. Adaptive restoration, native species enrichment, fire-risk reduction, hydrological monitoring, and biodiversity assessments become central. Scientific research is expanded, and participatory monitoring and stakeholder education are institutionalised components rather than optional add-ons. Moreover, climate modelling (RCP 2.6) is explicitly incorporated, making the activity set more forward-looking and climate-aligned.

Overall, the PFS activities move from operational forestry to integrated ecosystem management and climate adaptation, positioning the CSA as a provider of advanced environmental services rather than simply a forestry operator.

Key Resources

Resources in the BAU scenario include monitoring data (UAV and inventories), the OptFor-EU DSS, silvicultural expertise, and established networks of institutional partners. These reflect the inputs needed for standard forest planning and management.



The PFS significantly enlarges the resource base by incorporating TLS data, downscaled climate projections, and stronger modelling capacity. The inclusion of ESG- and climate-reporting data also reflects the integration of the CSA into broader environmental accounting systems. These upgraded resources improve analytical accuracy, future-risk estimation, and cross-sector data interoperability.

Overall, resource evolution from BAU to PFS demonstrates a clear upgrade from operational data to high-resolution, policy-relevant climate information and advanced modelling tools.

Value Proposition

The BAU value proposition is centred on sustainable wood production compatible with protected-area regulations, basic nature protection, and DSS-based scenario modelling for timber and ecosystem services. The added value is credible but relatively narrow—focused on compliance, production, and fundamental ecosystem assessments.

The PFS offers a far more comprehensive, multi-dimensional value proposition. It emphasises enhanced ecosystem resilience, improved carbon storage, scientific and recreational opportunities, and climate-smart management models. Importantly, it incorporates decision-support that integrates adaptation, mitigation, and economic considerations. The CSA also provides ESG and climate-reporting data, which substantially increases its institutional relevance and market value.

Overall, the PFS transitions from a sectoral forestry value model to a climate-focused, multi-benefit, cross-sector service provider.

Customer Relationships

In BAU, relationships rely on occasional consultation, intermittent community education, limited technical support, and tailored DSS services. Engagement is valuable but not continuous, and mainly transactional.

The PFS formalises ongoing co-development with stakeholders, continuous technical support, and structured community networks that extend beyond CSAs to include climate-focused clients. Participatory monitoring and expanded education programmes deepen local ownership and customer loyalty.

Overall, the PFS strengthens continuity, co-production, and high-value service relationships, improving user engagement and long-term collaboration.

Channels

The BAU scenario employs digital platforms, community meetings, workshops, and cooperation networks. It also uses ESG storytelling, largely as a communication accessory.



The PFS retains these channels but adds integration with GHG inventory systems, climate reports, and scientific conferences. This reframes channels from local and communication-oriented toward internationally recognised reporting frameworks and high-visibility scientific and policy platforms.

Overall, PFS channels increase the CSA's visibility, credibility, and alignment with national and EU climate-reporting structures.

Customer Segments

Customer segments in BAU include forest managers, protected area authorities, public administrations, research institutions, communities, and the timber sector. The main focus is on traditional forestry and conservation stakeholders.

The PFS maintains this base but introduces climate-finance institutions, green investment funds, climate ministries, and national GHG inventory bodies. This represents a significant broadening of the CSA's customer ecosystem, targeting actors with higher financial capacity and strategic relevance.

Overall, the PFS expands the client base from forest-sector users to climate-policy and climate-finance actors, opening new strategic markets and reinforcing long-term viability.

Cost Structure

In BAU, costs are primarily operational: monitoring, DSS integration, certification, planning, and legally required cutting and reforestation. These reflect a cost structure typical of traditional forest management.

In the PFS, the cost structure is more knowledge- and service-intensive: continuous DSS updates to reflect climate science, personnel development, community engagement, education, communication, and data management. While operational forestry costs decrease, investments shift towards governance, training, modelling, and communication.

Overall, PFS costs support higher-value services and long-term resilience, even though they may increase short-term expenditure on training and engagement.

Revenue Streams

The BAU model generates revenue from analytical services, consultancy fees, public funding, and private-company partnerships. Revenue is functional but strongly dependent on traditional funding schemes.

The PFS keeps these sources but introduces subscription-based access to data and DSS outputs, creating recurring revenue and scaling opportunities. The expanded customer base (climate finance, ministries) also increases revenue stability and potential growth.

Overall, the PFS diversifies revenue, reduces dependency on unstable traditional funding, and moves into more scalable, service-based business models.

Threats and Risks

Both scenarios share exposure to climate extremes, invasive species, habitat degradation, and stakeholder conflicts. These remain structural risks for any forest-based initiative.

However, BAU is additionally vulnerable to reliance on traditional funding and declining timber revenues. The PFS mitigates these by reducing dependence on timber and broadening financial channels, although it remains subject to uncertainties related to long-term climate change and policy volatility.

Overall, PFS reduces financial risk but faces more complex governance challenges and the need for continuous scientific updates.

Synthesis: Main Improvement Opportunities

1. Expand strategic partnerships to include climate-finance and climate-policy actors.
2. Upgrade monitoring and modelling resources by fully integrating TLS, RCP scenarios, and ESG data.
3. Shift from forestry operations to climate-smart ecosystem management as the core activity set.
4. Position the CSA as a provider of climate services, not only forestry services.
5. Strengthen co-production with stakeholders, enabling long-term participatory monitoring.
6. Develop recurring revenue models (subscriptions, climate reporting packages).
7. Enhance visibility and accountability through GHG inventory integration and scientific outreach.
8. Reduce reliance on timber-based revenues, moving toward nature-based solutions and carbon valuation.

10.3 Austria Business as Usual

AUSTRIA - BUSINESS MODEL CANVAS – BUSINESS AS USUAL

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom -up participatory approach, ensuring the indicators are feasible,



Partners	Activities	Value Proposition	Relationships	Customers
- Forest owner and forest manager - Tree orchard and nurseries - Local forest users (e.g. recreation, sport) - Research organizations - Forest authorities - Contractor (e.g. wood harvesting, transport) - Hunting licencees - Fishing licencees - Non-Governmental Organizations (e.g. WWF, Birdlife) - Individuals and companies interested in carbon credits	- Executing forest management practices - Developing future forest management, based on local knowledge and scientific evidence - Wild-life management (hunting) - Communicating impacts and benefits of forest management to politics and society	- Maintaining and/or increasing forest value (standing harvestable stock, carbon storage, other forest ecosystem services) - Mostly not-monetarily reimbursed services provided to public, individuals and stakeholder groups	- Networking in associations (e.g. Foresters association), public forum (e.g. Wald-Wild-Dialog, Wald-Dialog, Forst-Holz-Papier) - Client-Service provider relations - Personal private networks - Public advertising	- Wood-processing industry (Saw mills, Pulp mills, Paper mills) - Fuel wood producer - Bioenergy producer (e.g. biomass powerplants)
Threats/ Risks	Resources	Costs	Channels	Revenues
- Abiotic and biotic damage (e.g. European beech, Norway spruce) - Damage of young to middle-aged forest stands by wild animals - New diseases (e.g. Ash dieback) - Uncertainty in market developments (demand and supply) - Uncertainty in emerging carbon markets	- Forest management reports - Forest inventory data - Remote sensing data - Domestic (company-owned) labor, infrastructure and machines - Contractors (machines, labor, planning services)	- Forest management costs (especially afforestation and pre-commercial thinning cost and increased costs due to concentrated supply of harvestable timber in disturbance years) - Forest certification - Maintenance of infrastructure (e.g. roads, bridges, storage places) - Carbon assessment	- Personal networks (especially for hunting licencees) - Direct sale (e.g. high-value timber) - Long-term contracts (e.g. sawn timber) - Social media (especially for fuel wood)	- Timber sales - Hunting licencees - Fees for other non-timber forest use (e.g. mountain biking, horse-back riding) - Public sponsorships - Rental contracts (e.g. wind turbines, power lines, natural gas extraction and transport)

The following paragraphs present the BAU Case Study Area 5 (Austria), based on the BMC framework and drawing on the references and inputs provided by the CSA leaders.

Key Partners

The partnership landscape in the Austrian BAU scenario reflects a highly diversified forest governance system. Forest owners and managers sit at the centre, supported by nurseries and tree orchards that provide suitable material supply for forest regeneration. Local forest users—recreational groups, hunters, fishers—illustrate the multifunctional nature of Austrian forests, where social use is tightly integrated with economic and ecological functions. Research organisations provide scientific evidence for adaptive practices, while forest authorities play a regulatory and advisory role. Contractors support harvesting, transport and planning services, showing the sector's reliance on specialised external labour and machinery. NGOs (WWF, BirdLife, etc.) add a conservation-oriented counterbalance and influence social expectations. The presence of individuals or companies interested in carbon credits signals an emerging but still peripheral interest in climate-market mechanisms.

Overall, partnerships are broad and inclusive, but largely organised around traditional forest management functions, with emerging climate-oriented actors still at an exploratory stage.

Activities

Activities cover the full range of traditional forestry operations, from silviculture to harvesting. Forest managers combine practical know-how with scientific evidence to develop future-oriented management strategies, reflecting Austria's strong forestry education and professionalisation. Wildlife management is explicitly included, indicating the relevance of hunting both as an income source and as a tool to regulate ungulate pressure, which is a major threat to regeneration in many Austrian regions. Finally, communication of forest management impacts to society and politics is recognised as an activity—acknowledging increasing public scrutiny of forestry practices and the need for legitimacy-building in multifunctional landscapes.

Overall, forestry activities are robust and highly professionalised, firmly rooted in the logic of traditional silviculture, while increasingly complemented by communication and stakeholder engagement efforts that respond to evolving societal expectations.

Value Proposition

The value proposition centres on maintaining or enhancing forest value. This includes the standing harvestable stock, carbon storage, and a wide range of ecosystem services. Notably, many of these public-good services are not monetarily reimbursed,

reflecting a common challenge across European forestry: forest owners deliver societal benefits without corresponding revenue streams. This creates pressure on financial sustainability, particularly during disturbance years when unscheduled harvesting increases supply and depresses prices.

The BAU value proposition emphasises multifunctionality and long-term forest value, but lacks mechanisms to fully capture the monetary value of ecosystem services.

Customer Relationships

Relationships are built around professional networks and associations, reflecting Austria's strong forestry community. Platforms like Wald-Wild-Dialog and Wald-Dialog provide forums for negotiation between stakeholders (foresters, hunters, conservationists). Client-service provider relations are straightforward, especially in timber and contracting. Personal private networks play a non-trivial role, particularly in hunting-related services. Public advertising supports outreach and transparency.

Relationships rely on trust-based professional networks, but remain relatively traditional and interpersonal, with limited digitalisation or market diversification.

Customer Segments

The customer base is clearly industry-oriented: sawmills, pulp mills, paper mills, fuelwood producers and bioenergy plants dominate demand. These sectors depend on a stable supply of domestic wood, which makes Austrian forestry a key element of regional bioeconomy chains. However, the focus on industrial clients increases exposure to market fluctuations and sector-specific crises.

Customers are stable and long-standing, but heavily concentrated in wood-processing industries, offering limited diversification.

Threats and Risks

Forests face a combination of abiotic and biotic threats—including increasing damage to spruce and beech, ungulate browsing pressure, and emerging pathogens such as ash dieback. These risks are magnified by climate change, which has already increased disturbance frequency and intensity across Central Europe. Market uncertainty adds economic vulnerability, especially after disturbance events that generate oversupply. Uncertainty in emerging carbon markets reflects the early-development stage of climate-service monetisation in Austria.

BAU risks combine ecological instability with economic uncertainty, highlighting a sector that remains vulnerable despite high professional standards.



Resources

Resources include forest management reports, inventory and remote sensing data, and a strong mixture of internal and external labour and infrastructure. The presence of contractors indicates flexibility and responsiveness, while company-owned machinery ensures operational independence. The variety of data sources (inventory, remote sensing, reports) shows that information systems are well established, but it is unclear to what extent these are integrated or used for predictive, climate-adaptive planning.

Resource availability is strong and technically advanced, but the use of data for forward-looking, climate-resilient planning could be further expanded.

Costs

Cost structures reflect typical European forestry burdens: silvicultural operations (especially expensive pre-commercial thinning and afforestation), forest certification, and infrastructure maintenance. Disturbance years increase costs by concentrating harvests and requiring intensified management. Carbon assessment—still rarely monetised—adds administrative effort without guaranteed revenue.

Cost pressures are significant and can spike unpredictably due to disturbances, while some costs (e.g., carbon assessment) do not yet translate into returns.

Channels

Channels range from personal networks (especially important for hunting licences) to direct sales of high-value logs and long-term industrial contracts. Social media is increasingly used for fuelwood sales—showing a trend toward digitalised small-scale markets. However, the channel mix is still dominated by traditional, relationship-based and contract-based mechanisms, with limited innovation in digital service delivery.

Channels are reliable but traditional, with gradual digitalisation only evident in niche markets.

Revenue Streams

Revenues follow the classical multifunctional model: timber sales dominate, while hunting licenses and fees for recreational uses contribute secondary income. Public sponsorships support restoration or biodiversity actions, and rental contracts (e.g., wind turbines, power infrastructure) provide an increasingly important diversification element.

Revenue streams are diversified, but still heavily dependent on timber income, with non-timber streams contributing but not compensating for disturbance-driven fluctuations or non-remunerated ecosystem services.

Synthesis: Key Observations and Structural Challenges

1. Strong traditional forestry base, weak ecosystem-service monetisation: Austria's BAU model showcases high professional competence but limited capacity to financially capture the broad ecosystem services it provides.
2. High dependence on industrial wood markets: Timber remains central, exposing owners to price volatility, disturbance years and supply bottlenecks.
3. Rising climate risks: Disturbance events (windthrow, bark beetle, drought) and browsing pressure threaten regeneration and long-term productivity.
4. Fragmented and interpersonal customer relationships: Customer interactions rely heavily on personal networks, positioning the sector at risk of slow adoption of digital market mechanisms.
5. Cost increases without matching revenue mechanisms: Silviculture, infrastructure and certification costs increase under climate pressure, while new markets (carbon) are still uncertain.
6. Strong institutional and stakeholder networks: Austria's established forestry associations and dialogue platforms are major strengths and can support future adaptatio

10.4 Romania – Business as Usual vs. Preferred Future Scenario Comparison

ROMANIA - BUSINESS MODEL CANVAS – BUSINESS AS USUAL

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom-up participatory approach, ensuring the indicators are feasible,



Partners	Activities	Value Proposition	Relationships	Customers
- Ministry of Environment: The primary regulator approving management plans (Amenajamente). - INCDS "Marin Drăcea": The "Architects" designing technical norms. - Environmental Protection Agencies (APM/ANANP): Currently acting as gatekeepers, often rejecting the environmental report or the appropriate assessment report for forest management or the long response time. - Romsilva & Forest Guards: Enforcing strict compliance. - Logging Companies: Contractors focused purely on harvesting.	- Bureaucratic Navigation: Struggling to align with the new Forestry Code (Law 331/2024) and its modifications. - Drafting Environmental Studies: Commissioning "Appropriate Assessment Studies" (Studiu de Evaluare Adecvată) required for plan approval. - Sanitary Cuttings: Reactive removal of dead/infested trees (salvage logging). - Standard Forestry (Stalled): Attempting to apply clear-cuts/shelterwood, often delayed by lack of permits.	- Regulatory Compliance: Trying to adhere to the "Amenajament" to avoid penal/administrative sanctions. - Volume Production: Delivering consistent timber quantities for the construction and energy sectors. - Subsistence Security: Providing accessible firewood (capped at 5m3/ha for small owners).	- Transactional: Interactions are limited to sales auctions and timber exploitation licenses. - Top-Down/Regulatory: Managers act as enforcers of rigid laws rather than partners; relationships are often strained by bureaucracy.	- Wood Processing Industry: Large sawmills and furniture manufacturers requiring raw timber volume (m3). - Rural Households: Local communities dependent on firewood for heating (subsistence use). - State Budget: The government relies on revenue generated from state-owned forests (Romsilva).
Threats/ Risks	Resources	Costs	Channels	Revenues
- Legislative Paralysis: The 20-year plan requirement (Law 331/2024) blocks the approval process. - Permitting Blockage: Risk of Environmental Agencies rejecting environmental report and assessments, freezing all activity. - Climate Shocks: Simultaneous drought and pest outbreaks destroying the asset base.	- Monoculture Stands: Pure Spruce (EFT3), Beech (EFT6) and Quercus (EFT5) stands, which are currently high-risk assets (Drying - this aspect has started at national level with huge impact in the context of extrem events long periods of drought) - Traditional Machinery: Heavy equipment designed for extraction, often causing soil compaction. - Manual Labor: An aging and shrinking workforce in rural areas. - Expired Management Plans: Many forests operate on derogations because the new 20-year plan requirement is technically impossible	- High Regulatory Costs: Paying for mandatory Environmental Studies and repeated bureaucratic submissions. - Opportunity Cost: Massive financial loss due to the inability to harvest while waiting for approvals ("The Blocking Effect"). - Regeneration Costs: Repeated replanting due to drought failure.	- Public Auctions: The primary mechanism for selling standing timber to logging companies. - Physical Management Plans: Static, printed documents used to mandate activities. - Forest Districts: Physical offices managing local interactions.	- Timber Sales: The primary income, but value is declining due to quality loss (rot/discoloration) despite stable volumes. - Firewood Sales: Low-margin revenue stream. - No Payment for Services: No revenue is currently generated for water filtration or carbon storage. - Frozen Revenue: Income streams are frequently paused due to unapproved management plans.

ROMANIA - BUSINESS MODEL CANVAS – PREFERRED FUTURE SCENARIO

The set of indicators was developed by OptFor-EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom-up participatory approach, ensuring the indicators are feasible,

Partners	Activities	Value Proposition	Relationships	Customers
- Research Institutes (INCDS/Universities): Validating DSS data for legal use. - Environmental Agencies (APM): engaged as partners via transparent data sharing. - Agricultural Sector: Implementing agroforestry/shelterbelts. - Tech Providers: Drones/Sensors for monitoring. - Carbon/Bioeconomy Markets: Buyers of ecosystem services.	- Adaptive Management: Choosing between FM5/7 (Production) or FM6/8 (Carbon) based on specific stand needs. - Assisted Natural Regeneration: Prioritizing natural seeding to lower costs and improve genetics. - Hydrological Engineering: Restoring riparian buffers to retain groundwater. - Rapid Response: Drone-based monitoring for early pest/fire detection. - Policy Advocacy: Using project results to lobby against the 20-year rule, proving 10-year adaptive cycles are superior	"Regulatory Shield": Using DSS evidence to justify deviations from norms (e.g., shorter rotations) to the Ministry/INCDS. - Economic Resilience: Diversifying income through Carbon Credits and premium hardwood timber. - Disaster Avoidance: Proactive monitoring to prevent catastrophic asset loss.	- Co-Design: Managers collaborating with researchers to fix legislation. - Interactive: Real-time decision support via the DSS platform. - Advisory: Consulting for small owners on climate-smart forestry.	- Green Construction Industry: Demanding long-lived wood products (LLWP) for carbon storage. - Carbon Markets: Companies buying offset credits from "extensified" management (FM6/FM8). - Policy Makers: Using project data to reform national legislation. - Local Agriculture: Farmers benefiting from shelterbelts.
Threats/ Risks	Resources	Costs	Channels	Revenues
- Institutional Inertia: Risk that the Ministry does not accept DSS data for Environmental Assessments. - Market Volatility: Uncertainty in carbon prices. - Transition Gap: Financial strain on owners during the shift to new models.	OptFor-EU DSS: The central "Digital Evidence Locker" for compliance and planning. - Resilient Genetics: Access to drought-tolerant native seeds (Oak/Poplar). - Interdisciplinary Workforce: Personnel capable of interpreting DSS data for legal files.	- Upfront Tech Investment: Monitoring systems (drones, sensors). - Training Budget: Retraining staff on adaptive silviculture. - Initial Yield Reduction: Accepting lower timber volume in the short term (e.g., FM4 transition) to secure long-term value.	- Digital DSS Platform: Real-time decision support replacing static plans. - Policy Briefs: Direct advocacy channels to the Ministry. - Demonstration Sites: Showing neighbors that "Adaptive Management" works.	- Premium Timber: High-value hardwoods (FM5/7) and LLWP. - Payment for Ecosystem Services (PES): New revenue for water/carbon services. - Cost Avoidance: Saving money by not planting species that will die (Spruce) and by unblocking permits faster.

The following paragraphs present a comparison between the BAU and the PFS for Case Study Area 6 (Romania), based on the BMC framework and drawing on the references and inputs provided by the CSA leaders.

Key partners

In the Business as Usual (BAU) setting, partnerships are dominated by traditional institutional actors and regulatory authorities. These include the Ministry of Environment, INCDS “Marin Drăcea” (which contributes to silvicultural norms), Environmental Protection Agencies (APM/ANANP), RNP Romsilva, Forest Guards, and logging companies. The relationship is largely hierarchical and compliance-driven: authorities regulate, approve, or block management plans, while logging companies execute harvests with little flexibility. This creates a rigid, top-down structure with a strong regulatory bottleneck and limited innovation.

In the Preferred Future Scenario (PFS), the partnership landscape becomes more collaborative and diversified. Research institutes and universities validate DSS-generated data for legal use, making scientific partners co-designers of management solutions. Environmental agencies become active collaborators through transparent data sharing. New partners include tech providers for drone and sensor monitoring, the agricultural sector through agroforestry/shelterbelt integration, and carbon/bioeconomy markets interested in purchasing ecosystem services.

Overall, PFS replaces a rigid, compliance-oriented partnership model with a multi-sectoral innovation platform, increasing institutional agility and enabling legal reform.

Key Activities

BAU activities are highly constrained by regulation and bureaucracy. Managers focus on complying with strict management plans (“Amenajamente”), drafting mandatory environmental and appropriate assessment studies, and performing reactive sanitary cuttings to address drought and pest outbreaks. Standard silviculture—clear-cuts or shelterwood—often stalls due to permit delays. Activities are largely defensive: navigating administrative procedures, mitigating damage, and trying to avoid sanctions.

The PFS shifts toward proactive, adaptive and climate-informed forest management. Activities include choosing appropriate forest management intensities (FM5/7 for production or FM6/8 for carbon), assisted natural regeneration to reduce replanting costs, hydrological engineering to retain groundwater, and drone-based monitoring for early detection of fire or pests. In addition, managers actively engage in policy advocacy, using DSS evidence to propose reforms such as replacing the rigid 20-year planning cycle with more adaptable 10-year cycles.



Overall, activities transition from bureaucratically reactive to ecologically adaptive, enabling better climate resilience and reducing the administrative “freeze” that characterises the BAU situation.

Key Resources

In BAU, forest resources are dominated by high-risk monocultures—pure spruce, beech, or oak stands—already experiencing drought-induced decline. Machinery is traditional, often causing soil damage, and the labour force is aging and shrinking. Bureaucratically, the main resource—management plans—is outdated: many forests operate on derogations because fulfilling the 20-year planning requirement is technically impossible. These factors combine to create a resource base that is degraded, outdated, and vulnerable to climatic and administrative shocks.

The PFS introduces a more resilient and technologically advanced resource foundation. The OptFor-EU DSS becomes the central source of evidence for decision-making and legal compliance. Additional resources include access to drought-tolerant native seeds, an interdisciplinary workforce capable of interpreting digital data, and technology for real-time monitoring (drones, sensors). This resource base supports climate-adapted forestry while reducing dependence on rigid paper-based plans.

Overall, PFS replaces fragile ecological assets and outdated administrative tools with data-driven evidence, resilient genetics, and modern monitoring infrastructure.

Value Proposition

The BAU value proposition is severely limited. Timber remains the main revenue stream, but its value is declining due to rot and discoloration from climate stress. Firewood sales generate low margins and are mostly for subsistence. Crucially, forests provide no compensation for ecosystem services such as water filtration or carbon storage. Revenue is often “frozen” because unapproved plans prevent any harvesting, creating prolonged financial paralysis.

In the PFS, the value proposition expands and diversifies. Forest management becomes a source of verified climate benefits. Managers can justify deviations from norms using DSS evidence (“regulatory shield”), making compliance more flexible. Income diversification emerges through carbon credits, premium hardwood production, and climate-adapted long-lived products. Proactive monitoring reduces disaster losses, and adaptive management increases the long-term resilience and productivity of forests.

Overall, PFS transitions from a stagnating, timber-only model to a climate-resilient, multi-value forestry system capable of generating stable, diversified, and legally defensible revenue streams.

Customer Relationships

BAU relationships are transactional and bureaucratic. Most interactions occur through public auctions, timber licensing, and compliance enforcement. Managers are often positioned as rule enforcers rather than service providers or partners, leading to strained interactions, low trust, and minimal collaboration.

The PFS promotes collaborative and dynamic relationships. Co-design processes between managers and researchers help to revise legislation and improve management outcomes. Real-time DSS-supported decision-making enhances transparency and responsiveness, while advisory services help small owners adopt climate-smart practices. These interactions are more partnership-oriented and focused on problem-solving rather than punishment.

Overall, PFS replaces rigid, hierarchical relationships with engaged, knowledge-based, and cooperative interactions that improve both ecological and institutional performance.

Channels

In BAU, communication and operation channels rely heavily on outdated physical management plans, public auctions, and locally situated forest district offices. These channels slow administrative processes and contribute to the approval bottleneck affecting most forestry operations.

In the PFS, digital channels are at the core of the transformation. The DSS becomes a real-time planning system replacing static plans. Policy briefs provide direct communication with the Ministry. Demonstration sites create peer-to-peer diffusion of adaptive management practices. This multi-layered channel system supports advocacy, transparency, and practical demonstration.

Overall, the PFS replaces slow, paper-based channels with flexible, digital and policy-oriented communication pathways.

Customer Segments

BAU customers are traditional: large wood-processing industries, rural households depending on firewood, and the state budget through state-owned forests. These sectors demand volume and continuity, but not innovation.

The PFS diversifies and modernises customer segments. Long-lived wood product manufacturers, carbon-market actors, policy-makers seeking scientific evidence for legal reform, and agricultural actors using shelterbelts become central to the new market ecosystem. Demand shifts from raw volume to documented climate benefits, high-quality hardwoods, and ecosystem-service contributions.

Overall, PFS expands the customer base toward climate-driven markets, increasing long-term value and reducing dependency on conventional timber demand.



Cost Structure

BAU bears high regulatory costs due to mandatory environmental studies, repeated submissions, and compliance delays. Additional costs stem from regeneration failures linked to drought, and from the “blocking effect”—forests produce zero income while plans are unapproved.

In the PFS, costs concentrate on upfront technology investments, training and workforce development, and short-term yield reductions during transitions (e.g., replacing failing spruce with drought-tolerant species). However, these costs are offset by reduced replanting failures, faster permit approvals, and better long-term asset resilience.

Overall, while PFS requires higher initial investments, it significantly reduces sunk costs associated with bureaucratic delays and climate-induced failures.

Revenue Streams

BAU revenue streams are limited and unstable. Timber value decreases due to climate degradation, firewood sales offer minimal returns, and no payment is received for ecosystem services. Revenue freezes occur frequently when management plans remain unapproved.

The PFS creates multiple new revenue streams: premium timber (especially hardwood), payments for ecosystem services (water, carbon), and cost avoidance through successful adaptation measures. Faster approval processes also reduce non-productive periods. The cumulative effect is a more resilient revenue portfolio with climate-aligned opportunities.

Overall, PFS turns forests from passive, vulnerable capital into active providers of ecosystem and climate services.

Threats and Risks

BAU faces severe ecosystem-level risks—drought, pests, drying spruce stands—combined with legislative paralysis and permit blockage. These regulatory and climatic shocks compound, often halting management entirely.

The PFS introduces transitional risks: institutional inertia may slow acceptance of DSS data, carbon markets may fluctuate, and owners face potential financial strain during the transition. However, ecological risks decrease as adaptive management increases forest resilience.

Overall, BAU risks are catastrophic and structural, while PFS risks are transitional, manageable and primarily linked to policy acceptance and market maturation.

Synthesis: Main Improvement Opportunities (CSA6-Romania)

1. Implement adaptive management cycles, replacing the outdated 20-year plan requirement.
2. Integrate DSS into legal frameworks, enabling evidence-based flexibility and reducing bureaucratic blockage.
3. Promote drought-resistant species and assisted regeneration to reverse climate-induced declines.
4. Develop carbon and ecosystem-service markets to diversify revenues and support climate-finance flows.
5. Modernise monitoring through sensor and drone systems, enabling rapid response and damage prevention.
6. Strengthen institutional collaboration between forest managers, researchers and regulators.
7. Support small forest owners through advisory and training programmes, ensuring equitable access to new technologies.
8. Reform permitting workflows by introducing digital files, shorter review cycles and transparent data sharing.

10.5 Spain – Business as Usual vs. Preferred Future Scenario Comparison

SPAIN - BUSINESS MODEL CANVAS – BUSINESS AS USUAL

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom -up participatory approach, ensuring the indicators are feasible,



Partners	Activities	Value Proposition	Relationships	Customers
- Local and Regional authorities, Natural Protected Areas Administration - Universities and research groups - EIP AGRI Operational Groups - Forest owners: highly fragmented ownership - Forest owners association - Forest managers and farmers	- Timber harvesting - Preventive silviculture against forest fires - Post-forest-fire restoration - Forest planning and engineering - Recreational use of the forest: Hunting and fishing - Forest soil conservation - Land use planning (Project Mosaico)	- Post-wildfire forest restoration - Generation of carbon credits after post-fire restoration - Promotion of recreational use of the forest - Integration of agriculture and forestry (Mosaico Project) - Non-timber forest products (honey, mushrooms , hunting and fishing, cork ..)	- Forest owners' networking through Forest owners' association - EIP AGRI Operational Groups	- Forest Managers. - Certification and verification bodies - Companies purchasing carbon credits - Public administrations and policy makers - Local communities and territorial stakeholders - Forestry SMEs
Threats/ Risks	Resources	Costs	Channels	Revenues
- Wildfires: loss of carbon shrink - Desertification: soil erosion, loss of biodiversity and fertile land. - Drought: reduced growth and widespread mortality - Rural depopulation - Insects/Pathogens	- National Forest Inventory data, LIDAR - Scientific research (projects and publications) - Network and Research Projects in the case study area	- Harvesting and clearance costs - Monitoring and data collection - Use and integration of the OptFor-EU DSS - Forest restoration - Fire prevention and risk management	- Workshops and training sessions - Cooperation networks (universities, European Research projects, and Operational groups) - Regional Forest Management Plan and related instruments	- Carbon credit sales - Public funding (European research programs, national subsidies) - Timber industries

SPAIN - BUSINESS MODEL CANVAS –PREFERRED FUTURE SCENARIO

The set of indicators was developed by OptFor -EU to guide forest managers in assessing and enhancing the carbon mitigation potential of forests through informed management practices. The process followed a bottom-up participatory approach, ensuring the indicators are feasible,

Partners	Activities	Value Proposition	Relationships	Customers
- Local and Regional authorities, Natural Protected Areas Administration - Universities and research groups - EIP AGRI Operational Groups - Forest owners: highly fragmented ownership - Forest owners association - Forest managers and farmers - Local communities and young people	- Timber harvesting - Preventive silviculture against forest fires - Forest maintenance Post-forest-fire restoration - Biodiversity monitoring - Forest planning and engineering - Recreational use of the forest: Hunting and fishing - Forest soil conservation - Land use planning (Project Mosaico)	- Post-wildfire forest restoration - Generation of carbon credits after post-fire restoration - Promotion of recreational use of the forest - Integration of agriculture and forestry (Mosaico Project) - Non-timber forest products (honey, mushrooms, hunting and fishing, cork ..) - Use of the OptFor-EU DSS to estimate indicators and management scenarios for ecosystem service monetisation	- Forest owners' networking through Forest owners' association - EIP AGRI Operational Groups - Continuous technical support for DSS-based services customisation	- Forest Managers. - Certification and verification bodies - Companies purchasing carbon credits - Public administrations and policy makers - Local communities and territorial stakeholders - Forestry SMEs
Threats/ Risks	Resources	Costs	Channels	Revenues
- Wildfires: loss of carbon shrink - Desertification: loss of biodiversity and fertile land. - Drought: reduced growth and widespread mortality - Rural depopulation - Insects/Pathogens	- National Forest Inventory data, LIDAR - Scientific research (projects and publications) - Network and Research Projects in the case study area - Remote sensing free-data access	- Harvesting and clearance costs - Monitoring and data collection OptFor-EU DSS maintenance and update - Forest restoration - Fire prevention and risk management - Maintenance of reforested areas	- Workshops and training sessions - Cooperation networks (universities, European Research projects, and Operational groups) - Regional Forest Management Plan and related instruments	- Carbon credit sales - Public funding (European research programs, national subsidies) - Timber industries - Ecosystem services monetisation

The following paragraphs present a comparison between the BAU and the PFS for Case Study Area 7 (Spain), based on the BMC framework and drawing on the references and inputs provided by the CSA leaders.

Key Partners

In the BAU the partnerships are concentrated in the familiar regional governance and scientific network: local and regional authorities, natural protected-area administrations, universities and research groups, EIP AGRI operational groups, forest owners (notably highly fragmented ownership structures), forest owners' associations, forest managers and farmers. This constellation supports planning, research and operational coordination, with owners' associations playing an important role in aggregating highly fragmented supply.

For the PFS, partners remain largely the same core institutional actors, but include greater emphasis on local communities and youth engagement. The PFS implicitly expects stronger, ongoing collaboration between scientific/operational actors and communities (e.g., to support post-fire restoration, recreational services, and agroforestry integration). The presence of EIP AGRI groups suggests potential for continued cross-sector innovation and participation.

Comparison: The PFS does not introduce entirely new institutional actors but strengthens social inclusion (local communities, young people) and deepens collaborative links between science, authorities and practitioners. This enhances social legitimacy and long-term stewardship capacity—particularly important for landscapes prone to wildfires and depopulation.

Key Activities

BAU: Activity focus is on conventional and urgent tasks related to timber harvesting, preventive silviculture against fires, post-fire restoration, forest planning and engineering, recreational uses (hunting, fishing), soil conservation and land-use planning (Project Mosaico). Activities combine production, risk mitigation and multifunctional use, with a clear operational emphasis on restoring and protecting post-fire landscapes.

PFS: Activities largely mirror BAU but add or emphasize biodiversity monitoring and systematic use of OptFor-EU DSS for scenario estimation and ecosystem-service monetisation. The PFS retains preventive silviculture and restoration but situates them within a more explicit ecosystem-service framework and monitoring regime.

Overall, the BAU concentrates on operational responses to fires and standard multifunctionality. PFS integrates monitoring and decision-support tools to move from reactive restoration toward planned, evidence-based management that explicitly targets ecosystem-service outputs and potential monetisation.



Key Resources

The BAU includes available resources such as National Forest Inventory data, LiDAR, local research networks, and project outputs. Operational capacity rests on community labour, forest owner association coordination, and regional planning instruments (e.g., Regional Forest Management Plan).

PFS leverages the same geospatial and scientific resources but expects more systematic application of the OptFor-EU DSS as a central “digital resource” for indicator estimation and scenario testing. The scenario implicitly requires improved monitoring (continuity of LiDAR/NFI observations), data integration workflows, and human capacity to run and interpret DSS outputs.

Overall, PFS shifts resources toward data-integration and sustained monitoring, converting existing inventories and LiDAR snapshots into recurring, decision-grade information streams to support monetisation and adaptive management.

Value Proposition

In the BAU, the value proposition centers on post-wildfire restoration, limited generation of carbon credits following restoration actions, promotion of recreational uses, integration of agriculture and forestry through Project Mosaico, and provision of non-timber forest products (honey, mushrooms, cork, hunting).

The PFS retains BAU values but explicitly expands the proposition by using the OptFor-EU DSS to quantify and monetise ecosystem services. This enables a clearer, evidence-based offer: verifiable carbon and ecosystem service outcomes, improved biodiversity monitoring, and more credible recreational and NTFP (non-timber forest product) supply chains.

Overall, PFS enhances the credibility and marketability of the BAU value set—shifting from ad hoc restoration and NTFP production to verifiable, monetisable ecosystem services and evidence-backed management scenarios.

Customer Relationships

In the BAU, the relationships are largely institutional and transactional—owner associations and operational groups coordinate activities; public administrations and certification bodies interact through established channels; local stakeholders are engaged intermittently (e.g., for recreational planning or fire prevention exercises).

PFS anticipates more continuous technical support and customised DSS-based services. Relationships become more service-oriented and data-driven: co-creation with communities for restoration, ongoing support to buyers (e.g., carbon credit purchasers) for verification, and iterative interaction with policy makers using DSS outputs.



Overall, PFS converts intermittent, transactional links into sustained, trust-based relationships grounded in transparent data and co-development of management plans and monetisation schemes.

Channels

In the BAU, channels to stakeholders and markets are workshops, training sessions, cooperation networks (universities and EU research projects), and formal regional planning instruments. Public auctions or traditional market links are likely used for timber and local sales.

PFS retains BAU channels but relies more heavily on digital decision-support outputs (DSS reports, indicator dashboards) and structured instruments that facilitate ecosystem-service monetisation (e.g., verified carbon registries). Demonstration projects, targeted policy briefs and outreach to youth and communities appear as practical channels to boost adoption.

Overall, PFS augments conventional outreach with digital, evidence-based communication and formal monetisation channels that bridge local management and broader markets for ecosystem services.

Customer Segments

In the BAU, customers include forest managers, certification and verification bodies, companies buying carbon credits (if any), public administrations, local communities and territorial stakeholders, and forestry SMEs.

In the PFS the customer list is similar, but the nature of demand changes: customers seek verified ecosystem services, scenario-based planning outputs, and tailored technical support. This includes carbon credit buyers that require DSS-backed evidence, public institutions requiring monitored biodiversity outcomes, and local stakeholders demanding resilient recreational landscapes.

Overall, PFS narrows and upgrades customer expectations—buyers demand verifiability and performance metrics rather than simple volume or access, creating opportunities for higher-value engagements.

Cost Structure

In the BAU, costs are concentrated in harvesting and clearance, monitoring and data collection (ad hoc), use and integration of the OptFor-EU DSS (if used), restoration after fires, and fire-prevention actions.

In the PFS, costs are similar but are expected to be organised and perhaps frontloaded differently: sustained monitoring, DSS customisation and continuous technical support,



biodiversity monitoring programmes, and investments in capacity building for owners and managers to monetise services.

Overall, in PFS, operational costs are supplemented by investment in monitoring systems and ongoing DSS support—costs that enable revenue diversification but require upfront commitment and institutional support.

Revenue Streams

In BAU, revenues derive from timber industries, limited carbon credit sales after specific restoration actions, and public funding (European research programmes and national subsidies). NTFP and recreational uses provide localised income.

PFS retains these revenues and introduces more systematic ecosystem services monetisation supported by OptFor-EU DSS outputs. Carbon credit sales become more credible and potentially scalable; combined revenue streams may include payments for biodiversity or water-related services, enhanced tourism, and possibly premium markets for sustainably managed products.

Overall, PFS creates a clearer pathway to diversify and stabilise income by aligning monitoring, certification and DSS outputs with payment mechanisms for ecosystem services—improving bankability and investor confidence.

Threats and Risks

In the BAU, Key risks are high: wildfires (loss of carbon and habitat), desertification and soil erosion, drought-induced mortality, rural depopulation reducing local stewardship capacity, and pest/pathogen outbreaks. Fragmented ownership amplifies coordination challenges and reduces resilience.

In PFS, many BAU risks remain, but PFS mitigates them by strengthening monitoring, adaptive planning, and community engagement. New or residual risks include: the technical and institutional capacity to run and interpret DSS outputs; market risk for carbon and other ecosystem-service payments; potential inequity if monetisation benefits do not reach fragmented small owners; and the time lag between investment (monitoring, restoration) and realised revenue.

Overall, PFS reduces ecological and institutional vulnerabilities by improving evidence, coordination and revenue options, but introduces transitional risks related to capacity, equity, and market volatility.

Synthesis: Main Improvement Opportunities (Spain CSA7)

1. Operationalise the OptFor-EU DSS for monetisation: move from occasional DSS use to a formalised pipeline that produces verifiable indicators for carbon,

biodiversity and hydrological services suitable for payment schemes or certification.

2. Scale monitoring and data continuity: convert one-off LiDAR/NFI datasets into recurring monitoring (e.g., repeated LiDAR, targeted UAV transects, fixed plots) to support performance claims and adaptive management.
3. Strengthen local stakeholder inclusion and youth engagement: include communities and younger cohorts in restoration, sustainable recreation planning and NTFP value-chains to counter rural depopulation and build labour capacity.
4. Design equitable PES schemes: ensure that carbon and ecosystem-service revenues are structured to benefit fragmented small owners—consider pooled ownership/collective payment mechanisms via forest owner associations.
5. Integrate Project Mosaico outcomes into practical land-use incentives: operationalise agroforestry/land-use mosaics that increase landscape heterogeneity, reduce fire risk and open new revenue for farmers and owners.
6. Enhance fire-prevention investments: couple preventive silviculture with landscape-level fuel-break planning, community early-warning systems and targeted fuel treatments funded through blended public-private mechanisms.
7. Develop business models for NTFPs and recreation: professionalise honey, mushroom, cork supply chains and recreational services (guiding, concessions) to increase local income without expanding timber pressure.
8. Capacity building for certification and market access: provide training on verification protocols, carbon registry enrolment, and value-chain marketing to convert biodiversity and carbon performance into income.
9. Pilot demonstration sites: implement reference projects that combine DSS outputs, monitoring, PES enrolment and community governance to create replicable models for the wider region.

11 Common Improvement Opportunities Across CSAs

The proposed improvements for the different CSAs (Norway, Lithuania, Romania, and Spain) show a strong convergence towards modernizing forest management, diversifying the economy based on ecosystem services, and strengthening stakeholder inclusion.

Overall, the improvements for the CSAs should be directed toward strengthening the capacity to analyse and optimise the socio-economic and environmental trade-offs inherent in forest management decisions (Table 6). In line with the task description, the key objective is to better align model outputs with the Forest Ecosystem Services (FES) that guide decision-making. This requires improving the translation of modelled variables—such as harvest volumes, carbon fluxes, and ecosystem condition—into indicators that reflect economic viability, climate-mitigation performance, and ecological resilience.

In OptFor-EU, substantial progress has already been made along these improvement directions.

- (1) **Integration of carbon and ecosystem-service valuation:** The OptFor-EU DSS already provides the structural basis for linking stand- and landscape-level outputs to carbon accounting, biodiversity indicators, and service provisioning. Scenarios can now integrate PES-relevant variables, although anticipating how ecosystem-service markets will evolve remains challenging due to uncertain future regulatory frameworks and price signals.
- (2) **Modernisation of monitoring and decision-support tools:** The project has consolidated multi-source data streams (remote sensing, inventory, modelling, climate) into a harmonised analytical environment. The DSS operationalises scenario comparison and allows users to explore trade-offs dynamically, representing a significant technological advancement for all CSAs.
- (3) **Embedding adaptive and climate-smart management principles:** The scenario framework already includes silvicultural options reflecting adaptive pathways, species conversion, risk management, and climate projections. This enables the CSAs to test climate-resilient strategies; however, further work is required to quantify long-term socio-economic consequences, especially under volatile market conditions.
- (4) **Strengthening stakeholder inclusion:** Extensive co-production processes carried out in WP3 have ensured that local priorities, ownership structures, and socio-economic constraints inform scenario design. Workshops, interviews, and iterative feedback loops have contributed to tailoring the DSS and scenario space to stakeholder needs, reinforcing the legitimacy and usability of the results.

The improvements should aim to make the scenarios increasingly operational for decision-makers, more consistent with EU mitigation and adaptation priorities, and more responsive to the specific socio-economic challenges observed across the CSAs. OptFor-EU has already laid a substantial foundation—through the DSS, data integration, adaptive scenario design, and stakeholder co-production—but future extensions will be required to capture the uncertainty surrounding ecosystem-service markets and evolving economic conditions.

Table 6 – Summary of priority improvement areas across CSAs, organised by thematic domains and specific management, market, technological, and governance needs.

Thematic Area	Focus of Improvement	CSA1 (Norway)	CSA2 (Lithuania)	CSA6 (Romania)	CSA7 (Spain)
Monetization & Markets	Development of Carbon and Ecosystem Services Markets (PES/VERIFICATION)	Develop a coordinated national carbon-verification system.	Reduce reliance on timber, move towards carbon valuation.	Develop carbon and ecosystem-service markets.	Operationalise DSS for monetization and equitable PES. Capacity building for certification and market access.
	Support for Small Owners and Business Models	Support the transition (shared digital platforms, cooperatives).	Develop recurring revenue models.	Support through advisory and training programmes.	Design PES to benefit fragmented small owners. Develop business models for NTFPs and recreation.
Data & Technology	Modernization of Monitoring and DSS (Decision Support Systems)	Enhance the integration of digital tools	Upgrade monitoring and modelling (TLS, RCP scenarios).	Modernize monitoring (sensor, drone systems). Integrate DSS into	Scale up monitoring for data continuity (LiDAR, UAV, fixed plots).

		(traceability, LCA).		legal frameworks.	Operationalise OptFor-EU DSS.
Management & Climate Adaptation	Integration of Climate and Adaptive Strategies	Strengthen biodiversity safeguards.	Shift to climate-smart ecosystem management. Position as a climate service provider.	Implement adaptive management cycles. Promote drought-resistant species.	Integrate Mosaico outcomes (agroforestry). Enhance fire-prevention investments.
Stakeholder Inclusion & Collaboration	Strengthening Collaboration and Inclusion	Scale up collaborative innovation. Promote workforce development.	Strengthen co-production with stakeholders.	Strengthen institutional collaboration. Reform permitting workflows (digitalization).	Strengthen local stakeholder inclusion and youth engagement. Pilot demonstration sites (community governance).

The trade-off analyses must focus on the interactions between EU climate-mitigation objectives, forest managers' operational and economic goals, and the multiple Forest Ecosystem Services (FES) affected by different management scenarios. In line with the task description, the analyses need to clarify how alternative management pathways generate both benefits and burdens, and how these outcomes vary across CSAs. Specifically, the trade-off assessment should address four main dimensions:

1. **Trade-offs between climate-mitigation performance and economic viability.**
The analyses should quantify how carbon storage, CO₂ emissions from management operations, and the substitution potential of harvested wood interact with revenues, operational costs, and market conditions. This includes evaluating how different harvesting intensities or silvicultural strategies influence both mitigation outcomes and income generation.

2. **Trade-offs among different Forest Ecosystem Services.**
The assessment must consider how management scenarios alter the balance between timber production, biodiversity conservation, soil and water protection, recreation, and other cultural or regulating services. This includes identifying situations where enhancing one service reduces the provision or quality of another.
3. **Trade-offs between adaptation strategies and future risk exposure.**
The analyses should examine the costs and benefits of adaptive management options (e.g. species conversion, structural diversification, fire-prevention measures) in relation to their capacity to reduce vulnerability to climate-driven disturbances such as drought, storms, insects, and wildfire.
4. **Socio-economic trade-offs across alternative management scenarios.**
This includes assessing implications for small owners, cooperatives, and local enterprises; evaluating the cost-effectiveness of new FMP options compared with baseline practices; and analysing how scenarios influence employment, access to ecosystem-service benefits, and participation in emerging markets (e.g. PES).

12 Socio-Economic Implications of Forest Management Scenarios Across Case Study Areas

The socio-economic effects of forest management scenarios in each CSA are determined by the interplay between local socio-economic vulnerabilities, the current FMP, and the forest managers' perceptions regarding climate change and adaptation. The consensus among stakeholders across all CSAs is the economic vulnerability of forest managers due to factors like the complexity of regulatory compliance, rising costs, and low profitability.

12.1 General Socio-Economic Context for Scenario Development

The potential success of new FMP scenarios (like Adaptive Forest Management - AFM) and their resulting socio-economic effects depend on the characteristics of the forest managers, who can be broadly categorized into three types based on their adaptation to climate change, based on D5.3 outcomes:

1. **The Adapters:** Managers who are highly concerned about climate change, perceive high impacts on Forest Ecosystem Services (FES), and have already implemented various adaptation measures. Their socio-economic outcomes under new scenarios are likely positive, given their proactive approach.
2. **The Constrained:** Managers who are highly aware of climate change but are limited by external factors (e.g., funding, knowledge, regulations, ownership structure) in implementing new FMP. New scenarios that fail to address these constraints will have limited positive socio-economic effect in these areas.
3. **The Procrastinator:** Managers with low concern and low engagement in adaptation, who do not perceive a strong need for change⁶. Scenarios here require stronger policy instruments or economic incentives to generate socio-economic effects.

The socio-economic spectrum informing the scenarios includes key themes like Economic uncertainty and revenue, Cost efficiency, Policy instruments, and Cross-sectoral cooperation.

12.2 Socio-Economic Profile and FMP Context by CSAs

The socio-economic assessment across the CSAs highlights substantial variation in economic vulnerability, management intensity, and institutional capacity. These factors determine how forest management plans (FMPla) can be revised and where scenario design must prioritise cost efficiency, climate resilience, or market diversification.

The analysis of baseline conditions shows that several CSAs face high economic vulnerability, primarily linked to increasing management costs, regulatory complexity, and limited profitability (Table 7). In CSA1 and CSA2, compliance requirements and rising operational costs constrain the financial sustainability of forest owners, implying that new FMP scenarios must reduce administrative complexity while enhancing revenue potential. In CSA6 and CSA7, structurally low profitability remains the dominant barrier; therefore, scenario development must prioritise cost-efficient management alternatives and policy instruments capable of improving economic returns.

Table 7 - Summary of socio-economic challenges, baseline forest management contexts, and economic implications for scenario development across the CSAs. The table outlines how differing vulnerabilities, management practices, and market conditions shape the priority

CSA	Key Socio-Economic Challenge	FMP Baseline & Scenario Context	Economic Implications for Scenarios
CSA1	Economic vulnerability due to complexity of compliance and rising costs.	Current FMP includes standard harvesting practices.	Scenarios (FMP changes) must primarily focus on reducing complexity of compliance and increasing revenue to justify rising costs.
CSA2	Economic vulnerability due to complexity of compliance and low profitability .	Current FMP involves main, silvicultural, sanitary, and special cuttings.	A strong focus on Cost efficiency is required in new FMP scenarios to address low profitability, alongside simplifying compliance.
CSA3	Insufficient compensation/insurance for financial losses under climate change.	FMP includes minimum intervention woodland and ancient semi-natural areas.	Scenarios require innovative financial tools (e.g., specific insurance or compensation mechanisms) to secure the socio-economic future of these protected forest areas.

CSA4	Economic vulnerability due to rising costs .	The area has suffered extensive damage (approx. 40,000 hectares of newly open areas) from storms, drought, and insect infestations in <i>Picea abies</i> stands. High-resolution simulations for new FMP are being conducted here.	Socio-economic effects of new scenarios (e.g., afforestation, species conversion) will be critical for local recovery and mitigating future economic losses from natural disturbances.
CSA5	Economic vulnerability due to rising costs .	Vienna Woods Biosphere Reserve, where about one-quarter of the forests are unmanaged . Dominant species are <i>Fagus sylvatica</i> .	Scenarios must balance commercial goals with the significant unmanaged forest area. The socio-economic effects will be judged by the ability of new FMP to secure timber revenue while maintaining cultural and recreational benefits , which stakeholders prioritize alongside timber.
CSA6 & CSA7	Economic vulnerability due to low profitability .	FMP data is used for high-resolution model simulations in CSA6. CSA6 and CSA7 showed the highest engagement in cross-sectoral cooperation.	Scenarios in these areas must focus heavily on Cost efficiency and the Policy instruments that can improve economic returns. High cooperation (CSA6-CSA7) suggests new FMP are more likely to be adopted.
CSA8	Timber market instability and lack of financial tools impede long-term sustainability and resilience.	A high percentage (around 24%) of forests are unmanaged, often due to the high cost of harvesting .	Scenarios require FMP changes that address the high cost-to-revenue ratio in harvesting and a focus on financial tools to stabilize the timber market, thus alleviating the current socio-economic instability.

To construct a meaningful comparison between BAU and PFS, and to assess their socio-economic implications, it is essential to integrate the insights generated in WP3. Stakeholder perspectives collected across the CSAs provide critical contextual knowledge that cannot be captured solely through modelling or economic indicators. WP3 results clearly show that the socio-economic effects of forest management scenarios depend on their ability to:

1. improve cost efficiency and profitability in CSAs with low economic returns (CSA2, CSA6, CSA7, CSA8);
2. enhance financial protection against climate-change impacts—particularly through compensation or insurance mechanisms—in vulnerable areas (CSA3, CSA8);
3. support large-scale adaptive forest management practices in regions experiencing severe climate-induced damage (CSA4);
4. diversify markets and strengthen community engagement so that forests continue to provide cultural and recreational benefits alongside timber production (all CSAs).

These insights are indispensable for interpreting the potential benefits and limitations of each scenario and for understanding how management choices resonate with the needs, vulnerabilities, and priorities of local actors.

In summary, the socio-economic effects of management scenarios are being on their ability to (Table 8):

1. Increase **Cost efficiency and profitability** in CSAs with low economic returns (CSA2, CSA6, CSA7, CSA8).
2. Provide **financial protection** against climate change impacts (compensation/insurance) for vulnerable areas (CSA3, CSA8).
3. Support large-scale **adaptive FMP** in regions with high climate change damage (CSA4).
4. Promote **market diversification** and **community engagement** to ensure forests provide cultural and recreational benefits alongside timber (all CSAs).

In fact, a comprehensive scenario analysis must take into account the contextual differences identified in previous Deliverables—particularly D2.1, D3.2, and D5.3—which document the heterogeneous levels of economic vulnerability, environmental protection, and management intensity across the eight CSAs. Table 8 summarises these differences and highlights why trade-offs will potentially vary substantially from one CSA to another. This variability reinforces the need for context-specific indicators, acknowledging that not all indicators will be equally relevant or applicable across all CSAs; their use will depend on the selected scenarios, data availability, and local management objectives.

In this sense, integrating WP3 findings together with the baseline characterisation from WP2 and the socio-economic analyses in WP5 forms the foundation for interpreting scenario outcomes and preparing the full trade-off assessment that will be completed once WP2 model outputs are incorporated into WP4's DSS in the Month 40 follow-up report.

Table 8- Comparative overview of economic vulnerability, environmental protection levels, and forest management intensity across the eight CSAs. Values are derived from D2.1, D3.2, and D5.3 and inform the identification of context-specific management needs and trade-offs.

CSA	Country	Economic Vulnerability	Environmental Protection	Management Intensity
CSA1	Norway	● High	● 5.8%	● Moderate (0.6% harvest, 1.4% replant)
CSA2	Lithuania	● High	● 18%	● Moderate (continuous reforestation)
CSA3	UK	● Medium	● High (ancient woodland)	● Low (limited commercial use)
CSA4	Germany	● High	● Moderate	● High (rotation 80–120 yrs)
CSA5	Austria	● High	● Moderate	● Moderate-High (rotation 80–120 yrs)
CSA6	Romania	● High	● 25% unmanaged	● Moderate (selective logging)
CSA7	Spain	● High	● 12% unmanaged	● Moderate-Low (multifunctional)
CSA8	Italy	● High	● 25% unmanaged	● Low (24% unmanaged, conservation focus)

Legend:

- High, ● Moderate, ● Low
- Economic vulnerability considers profitability and regulatory complexity.
- Environmental protection represents strictly protected / unmanaged forest area.
- Management intensity reflects harvest activity, reforestation, and commercial exploitation.

12.3 Socio-Economic Indicators Extracted from the CSAs

The socio-economic indicators presented below constitute the analytical basis for assessing trade-offs across the CSAs. These indicators represent the dimensions of economic performance, social engagement, and governance capacity that are most relevant for evaluating the implications of alternative forest management scenarios. They have been selected because they correspond to variables that can be quantified using: (1) modelled outputs already available in the OptFor-EU DSS (e.g., harvest volumes, management intensity, carbon flows, area under different regimes); (2) information gathered through stakeholder engagement activities in WP3 (e.g., ownership structure, local employment, traditional land-use systems, community participation); and (3) socio-economic datasets and valuation inputs developed in WP5 (e.g., NTFP value, PES mechanisms, economic risk indicators).

Although not all indicators can be computed for every CSA—due to data heterogeneity, differences in forest ownership regimes, and variation in local socio-economic structures—the framework provides a coherent set of metrics from which a relevant subset can be selected for each area. This approach ensures comparability while allowing flexibility to reflect CSA-specific conditions.

The indicators cover three main dimensions:

- **Economic indicators (Table 9)**, which capture diversification of forest products, profitability, management intensity, market integration, employment potential, and the availability of financial resources;
- **(ii) Social indicators (Table 10)**, which reflect demographic dynamics, community involvement, cultural and recreational values, technical capacity of forest owners, and dependence on forest-based livelihoods;
- **(iii) Institutional and governance indicators (Table 11)**, which assess management planning capacity, ownership fragmentation, public and private governance structures, funding adequacy, and risk-management practices.

Together, these variables allow the project to quantify how different forest management scenarios influence socio-economic outcomes, identify where trade-offs emerge between economic viability and ecosystem-service provision, and support decision-makers in evaluating policy or management interventions. When appropriate, the indicators can also be aggregated into composite indices (Table 12) to provide an integrated representation of economic vitality, governance efficiency, management capacity, social engagement, or sustainability risk. These composite metrics help synthesise complex system interactions and offer a clear basis for comparing scenarios within and across CSAs.

Table 9 - Economic indicators proposed for assessing socio-economic performance across the CSAs, including descriptions, units of measurement, and specific quantifiable metrics derived from DSS outputs and WP3–WP5 data.

Indicator	Description	Possible Units of Measurement (Metrics)	Specific Quantifiable Indicators
Forest Product Diversification	Timber, resin, cork, firewood, honey, and hunting are mentioned as economic outputs.	Percentage (%) ; Value (€/ha/year) ; Number of products	% of Total Revenue from Non-Timber Forest Products (NTFPs) / Total Revenue; Number of Forest Product Types (wood + non-wood) sold annually; Total Economic Value (€) of NTFPs per hectare.
Forest Productivity / Profitability	Managed forests (Pinus pinaster, Quercus spp.) have defined rotation ages and thinning schedules aimed at optimizing yield.	Volume (m³/ha/year) ; Rate (%) ; Value (€/ha/year)	Mean Annual Volume Increment (MAI) (m ³ /ha/year) compared to regional average; Return on Investment (ROI) for forest operations; Net Profitability (€/ha/year) after management costs.
Economic Use Intensity	Different management intensity between productive forests (BAU) and non-managed (NOM) forests.	Area (ha) ; Percentage (%) ; Man-days per hectare	% of Forest Area under active management plans; Intervention Density (e.g., timber harvesting in m ³ /ha); Labour Intensity (man-hours/ha) for forest operations.
Access to Financial Resources	Public forests face “lack of economic resources for forest planning and management.”	Value (€/ha/year) ; Percentage (%)	Annual Public and/or Private Spending (€/ha) for forest planning and management; % of Financial Need covered by funds (public/private/EU); Number of Financing Projects (PES, Carbon) approved.

Employment Potential in Forest Operations	Implied through resin tapping, timber harvests, and grazing; limited by abandonment.	Units (n.); Rate (%)	Number of Full-Time Equivalent (FTE) Jobs per 100 hectares of managed forest; Youth Employment Rate (under 35) in forest activities; Number of Active Companies/Cooperatives in the sector (e.g., resin, cork).
Market Orientation	Resin and timber forests show market-oriented management; NOM forests do not.	Percentage (%); Rate (%)	% of Volume / Value of Forest Products entering certified supply chains (e.g., FSC®, PEFC); Rate of Owner Adherence (%) to collective management or sales platforms (cooperatives).
Ecosystem Service Valuation (Non-Market)	Forests provide biodiversity, hydrological regulation, erosion control, and tourism.	Value (€/ha); Score (index); Units (n.)	Total Economic Value (€/ha) of ecosystem services calculated using valuation methods (e.g., Rate of Carbon Sequestered tCO ₂ /ha/year); Biodiversity Index (e.g., species richness); Number of Visitors or revenue from ecotourism (€/year).
Ownership Fragmentation Impact	High rate of private ownership fragmentation reduces economic feasibility of management.	Size (ha); Percentage (%)	Average Size of Private Lot (ha); % of Owners adhering to collective management schemes (associations, consortia); Additional Transaction Cost (€) due to fragmentation.
Land Abandonment Rate	"High number of abandoned forest	Area (ha); Rate (%)	Total Area (ha) of forest land classified as "abandoned" or without

	areas" mentioned explicitly.		active management; Conversion Rate (%) of managed areas to abandoned areas over the last decade.
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Table 10 – Social indicators relevant for assessing community engagement, demographic trends, traditional land-use systems, and socio-cultural values across the CSAs.

Indicator	Description	Quantifiable Metrics (Unit of Measurement)
Rural Population Decline / Abandonment	Directly linked to non-management and fire risk.	Annual Population Change Rate (%) in core forest municipalities; Land Use Change (ha) : Area of agricultural/grazing land converted to unmanaged shrubland/forest.
Local Community Involvement	Low, inferred from lack of management and awareness of land ownership.	Number of active community governance bodies (e.g., fire prevention committees, forest owner associations); Attendance Rate (%) at public consultations on forest management plans.
Knowledge and Technical Capacity	"Lack of technical skills of private owners."	Owner/Manager Training Rate (%) : Percentage of forest owners receiving technical training annually; Average Score on technical skills assessment (e.g., DSS use, CTNF principles).
Traditional Land-Use Systems	Dehesas as long-term agro-silvo-pastoral systems — traditional human management shaping the landscape.	Area (ha) under traditional agro-silvo-pastoral management (e.g., Dehesas); Productivity/Revenue (€/ha) from traditional NTFPs (cork, resin) or grazing.
Dependence on Forest for Livelihoods	Extensive grazing, cork, firewood, and resin production imply local economic reliance.	% of Household Income derived from forest-based activities in the local area; Total Value (€) of NTFP output per year.

Awareness of Property Ownership	“Owners often not even aware of their land.”	Property Registration Rate (%) : Percentage of private forest parcels with up-to-date and verified ownership records; Inquiry Rate : Number of owner inquiries/participations in cadastral updates per year.
Cultural and Recreational Value	Forests support tourism and traditional uses (fishing, grazing, cork).	Annual Revenue (€) generated from certified recreational services (e.g., guiding, concessions); Number of Visitors or user days in recreational areas.

Table 11 - Institutional and governance indicators capturing ownership structures, management capacity, coordination mechanisms, and risk-management policies across the CSAs.

Indicator	Description	Quantifiable and Usable Metrics (Unit of Measurement)
Ownership Regime Diversity	Coexistence of public and private forests with different management structures.	Area Breakdown (%) : Percentage of forest area by ownership regime (public vs. private vs. communal). Fragmentation Index : Average number of parcels per private owner.
Effectiveness of Public Management	“Formal forest management, although not entirely efficient.”	Plan Implementation Rate (%) : Percentage of planned interventions (e.g., logging, preventive silviculture) executed annually in public forests. Budget Deviation (%) : Discrepancy between the allocated and actually spent management budget.
Private Forest Governance	Private owners lack coordination and technical/economic support.	Association Membership Rate (%) : Percentage of private forest area covered by owner associations or cooperatives. Number of Collective Plans : Number of Forest Management Plans (FMPla) drafted for groups of private owners.

Planning and Management Capacity	Public forests have management plans but insufficient funding; private forests often unmanaged.	FMP Coverage (%): Percentage of total forest area (public + private) covered by valid and approved FMPla. Planning Funds (€/ha): Average funding available per hectare for drafting and updating FMPla.
Risk Management Policies	Mention of fire, pests, drought, and erosion threats due to poor management.	Preventive Treatment Area (ha/year): Forest area treated annually with preventive measures (e.g., firebreaks, sanitation thinning) vs. the high-risk area. Response Time (hours/days): Average time to implement measures against infestations or hydrogeological hazards.
Institutional Support for Forest Owners	Implied absence of technical assistance or cooperative structures.	Technical Service Rate (n./year): Number of man-days or hours of technical advice provided to private owners per year. Cooperation Funding (€): Public funds specifically dedicated to supporting the creation of private cooperative structures.

Table 12 - Composite indicators proposed for evaluating integrated socio-economic, governance, and sustainability dimensions across CSAs, including component metrics and index rationale.

Composite Indicator	Possible Components	Specific Quantifiable Metrics (Examples from Previous Analysis)	Rationale of the Index
Economic Vitality of the Forest Sector	Share of managed forests X diversity of products X market orientation	* Managed Share: % of Forest Area under active management plans. * Diversity: % of Total Revenue from Non-Timber Forest Products (NTFPs).	Measures the sector's ability to generate diversified, sustainable, and market-validated income.

		* Market Orientation: % of Volume/Value of certified products (FSC®/PEFC).	
Forest Management Capacity	% forests under active management X availability of technical skills X financial support	* Active Management: % of Forests under active management. * Competence: Owner/Manager Training Rate (%). * Financial Support: Annual Public/Private Spending per hectare (€/ha).	Evaluates the operational readiness (human, technical, and financial capital) of the territory to implement modern management.
Social Engagement in Forestry	Level of owner awareness X community participation X continuity of traditional uses	* Awareness: Verified Property Registration Rate (%). * Participation: Number of active community governance bodies. * Traditional Uses: Area (ha) under traditional agro-silvo-pastoral management.	Measures the human and cultural capital, which is fundamental for preventing abandonment and ensuring long-term stewardship.
Governance Efficiency	Presence of management plans X funding adequacy X degree of ownership fragmentation	* Planning: Forest Management Plan (FMPla) Coverage (%). * Financial Adequacy: % of Financial Need covered by funds. * Fragmentation: Private Association Membership Rate (%).	Evaluates the effectiveness of institutional structures in providing planning, resources, and coordination to overcome structural obstacles.

Forest-Related Sustainability Risk Index	Fire risk X land abandonment X biodiversity/ecosystem service values	* Abandonment: Conversion Rate (%) of managed areas to abandoned areas. * Fire Risk: Untreated area in high-risk zones vs. total area. * Ecosystem Value: Biodiversity Index (or Total Economic Value of ecosystem services).	Measures the overall vulnerability of the forest system to ecological, climatic, and socio-economic threats.
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13 Necessity of Active and Cross-Sectoral Engagement

To overcome the data collection difficulty and ensure the effectiveness of the proposed improvements, a profound change in the governance model is essential, built on active and coordinated engagement:

1. **Involvement of Forest Owners:** Success in counteracting ownership fragmentation and land abandonment hinges on increasing the Private Association Membership Rate. Owners must transition from being subsidy recipients to active partners in data co-production (e.g., participatory monitoring) and Collective Forest Management Plans (FMPla), first addressing the fundamental issue of low Awareness of Property Ownership.
2. **Involvement of the Entire Forest Value Chain:** The diversification of products (NTFPs) and the monetization of ecosystem services (Carbon) require the integration of the entire chain—from technology providers (DSS) to end-users of certified products (Market Orientation). This strengthens local employment (Employment Potential) and ensures investments lead to greater Net Profitability.
3. **Strengthening Governance:** Institutional indicators highlight a lack of technical support and low Public Management Effectiveness (Plan Implementation Rate). It is critical to strengthen institutional collaboration and simplify workflows (Permitting Workflow Efficiency), ensuring that funding for planning and risk management is adequate and utilized effectively (Planning Funds/ha).

14 Conclusions

The analysis conducted in this Deliverable demonstrates the growing socio-economic relevance of sustainable forest management in the context of climate change, the circular bioeconomy, and community resilience. Forests are increasingly recognised not merely as sources of timber, but as multifunctional assets capable of delivering climate mitigation, ecosystem services, rural development, and economic diversification.

This work represents the first phase of Task 5.4, which aims to assess the socio-economic and environmental trade-offs of alternative forest management scenarios across all CSAs. As outlined in the Task description, the full trade-off and optimisation analysis depends on the integration of WP2 model outputs, WP3 stakeholder knowledge, and WP5 socio-economic data. In the current Deliverable (M33), key WP2 outputs—such as detailed simulated harvest levels, carbon fluxes, species dynamics, disturbance probabilities, material and energy pathways, product lifetimes, and harvesting technology parameters—are not yet available. Consequently, the analysis presented here focuses on establishing the socio-economic foundations needed for interpreting trade-offs once the complete dataset is implemented within the WP4 DSS.

Despite these constraints, several cross-cutting conclusions can already be drawn:

1. **Transitioning from traditional forestry to climate-smart forestry requires systemic change.** BAU scenarios remain constrained by regulatory rigidity, limited digitalisation, dependence on timber markets, and vulnerability to disturbances. Preferred Management Scenarios (PMS) indicate that integrating the OptFor-EU DSS, climate-adapted silviculture, and nature-based solutions can significantly enhance resilience, decision-making flexibility, and long-term socio-economic viability.
2. **Socio-economic indicators are essential for guiding strategic planning and monitoring.** Economic outputs alone cannot capture the full range of values forests generate. Social indicators—such as participation, well-being, institutional capacity, or equity—remain underdeveloped but are essential for long-term sustainability assessment. Combining economic, social, and ecological metrics enhances both the legitimacy and robustness of forest-related decisions.
3. **New revenue streams can improve financial stability and reduce risk.** Carbon markets, PES schemes, bio-based materials, and long-lived wood products offer opportunities to diversify income and reduce exposure to volatile timber prices. Monetising ecosystem services remains an underused but promising strategy for future management systems.
4. **Digitalisation is a key enabler of innovation.** The integration of drones, LiDAR, TLS, and advanced modelling systems increases monitoring precision, risk

assessment capabilities, and transparency. The OptFor-EU DSS will be central to enabling scenario-based planning and science-informed governance.

5. **Cross-sectoral partnerships and stakeholder engagement are necessary for long-term impact.** Effective transformation requires coordinated action among forest owners, researchers, policymakers, climate-finance actors, environmental authorities, and local communities. Participatory processes foster social acceptance, policy alignment, and co-development of resilient management strategies.

One of the key contributions of this Deliverable is the identification of a **preliminary set of economic, social, and combined socio-economic indicators** to be used in future trade-off assessments. These indicators were derived from stakeholder-generated Business Model Canvas (BMCs), cross-CSA comparisons, and WP5 expertise.

Importantly, **not all indicators will be used uniformly across all CSAs**. Instead, indicator selection will be **context-dependent**, reflecting:

- the characteristics of each CSA,
- the specific management scenarios analysed (BAU vs PMS),
- the priorities expressed by stakeholders, and
- the availability and suitability of WP2 model outputs.

This adaptive approach ensures that trade-off analyses remain **relevant, realistic, and sensitive to local conditions**, while still enabling cross-case comparison where appropriate.

A second Deliverable at **Month 40** will build on this work by incorporating the full suite of WP2 modelling data. This follow-up report will:

- execute a complete quantitative trade-off and optimization analysis,
- align model outputs with the FES/EFMI frameworks,
- evaluate trade-offs between EU mitigation targets, forest manager objectives, and ecosystem-service provision,
- integrate indicators into the WP4 DSS,
- support the development of policy recommendations (Task 5.5).

This expanded analysis will offer the quantitative evidence base required to guide forest managers and policymakers toward resilient, climate-smart, and decarbonisation-oriented strategies for Europe's forests.

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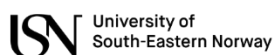
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