Deliverable

D4.3 Advice on governance structures for a permanent monitoring and pathway assessment system, and a reporting and accounting framework for the LULUCF sector

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Author/s	Klemens Schadauer (BFW), Stephan Graeber (BFW), Annemarie Bastrup-Birk (EEA), Marco Ferretti (WSL), Daniel Di Marzo (ALUFR), Kari T. Korhonen (LUKE), Johannes Breidenbach (NIBIO)
Reviewer/s	Daniela Kleinschmit (ALUFR), Jo House (UB)
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III. Abbreviations

NIBIO	Norwegian Institute of Bioeconomy Research
ALUFR	Albert-Ludwigs University Freiburg
IGN	National Institute of Geographic and Forest Information
VUA	Vrije Universiteit Amsterdam
TI	Thünen Institute of Forest Ecosystems
CFRI	Croatian Forest Research Institute
LUKE	Natural Resources Institute Finland
BFW	Federal Research and Training Center for Forests, Natural Hazards and Landscape
GIS	Slovenian Forestry Institute
UHUL	Czech Forest Management Institute
VTT	Technical Research Centre of Finland Ltd.
CSIC	Consejo Superior de Investigaciones Científicas
CICERO	Center for International Climate Research
UGOE	University of Göttingen
UH	University of Helsinki
TM	TreeMetrics
EVINBO	Eigen Vermogen van het Instituut voor Natuur- en Bosonderzoek
ELO	European Landowners Organisation
IEFC	Institut Européen de la Forêt Cultivée
FMI	Finnish Meteorological Institute
WSL	Swiss Federal Research Institute for Forests Snow and Landscape Research
UB	University of Bristol
JRC	Joint Research Center
EEA	European Environmental Agency
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
EFM	European Forest Monitoring
EFMR	European Forest Monitoring Regulation
EFMS	European Forest Monitoring System
NFI	National Forest Inventory
ENFIN	European National Forest Inventory Network
GFRA	Global Forest Resource Assessment
SoEF	State of European Forests
EU	European Union
CLTRAP	Convention on Long-range Transboundary Air Pollution
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
EB	Executive Body
TF	Program Task Force
EC	European Commission
PCC	Programme Co-ordinating Centre
FRA	Forest Resources Assessment
LULUCF	Land Use, Land Use-Change and Forestry
FISE	Forest Information System for Europe
DG	Directorate General
UNECE	United Nations Economic Commission for Europe
FAO	Food and Agricultural Organisation of the United Nations
ETC-BD	European Topic Centre on Biological Diversity
EFI	European Forest Institute

GOZDIS	Slovenian Forestry Institute
MS	Member State
SFMOs	State forest management organisations
EUSTAFOR	European State Forest Association
CEPF	Confederation of European Forest Owners
MTK	The Central Union of Agricultural Producers and Forest Owners
COPA-COGECA	Comité des organisations professionnelles agricoles - Comité général de la coopération agricole de l'Union européenne
ELO	European Landowner's Organization
WWF	World Wide Fund for nature
FERN	Forests and the European Union Resource Network
CDP	Carbon Disclosure Project
FTP	Forest-based Sector Technology Platform
CEI-Bois	European Confederation of Woodworking Industries
EPF	European Panel Federation
EFIC	European Furniture Industries Confederation
CEPI	Confederation of European Paper Industries
FSC	Forest Stewardship Council
PEFC	Programme for the Endorsement of Forest Certification
GCF	Green Climate Fund
GIIN	Global Impact Investing Network
EIB	European Investment Bank
EBRD	European Bank for Reconstruction and Development
RS	Remote Sensing
NGO	Non-governmental Organisation
AHWP FM	Ad-hoc Working Party on Forest Monitoring
LAI	Leaf Area Index

1. Contents

1. Summary

The PathFinder project aims to develop and demonstrate an innovative integrated forest monitoring and pathway assessment system for Europe. Continuous forest monitoring is key for ensuring that goals are met and allows for the adaptation of pathways so goals can be reached with a minimum of trade-offs. A suitable governance structure is fundamental for the successful implementation of a European Forest Monitoring System (EFMS). Work package 4 of the PathFinder project aims to support policymaking and implementation and to co-design policy pathways that demonstrate the functionality of the integrated forest monitoring and pathway assessment system developed in PathFinder. This deliverable highlights historical and recent developments in European Forest Monitoring and identifies relevant steps for implementing a governance structure of a EFMS.

The proposed governance structure for a European Forest Monitoring System (EFMS) adopts a stepwise, bottom-up approach, leveraging existing national-level data collection efforts and standardising information at the European level.

Key actors in this structure include the European Commission, European Environment Agency (EEA), Member States, European National Forest Inventory Network (ENFIN), and ICP Forest (ICPF). ENFIN and ICPF, both serving as expert groups, offer distinct areas of monitoring focus; ENFIN concentrates on forest structure, land use, and biodiversity, whereas ICPF targets forest health and vitality. Additionally, both groups provide expertise on monitoring forest soils. Each of these actors plays a critical role in ensuring the collection, analysis, and dissemination of high-quality forest data. Consequently, this collaborative effort ensures the monitoring system's capacity to support evidence-based policymaking and contribute to the resilience and sustainability of European forests.

To meet the goals of the EFMS, a clear structure for decision-making is needed. We therefore propose

- The European Commission holds responsibility for the overall coordination of the monitoring system.
- The European Commission, Member States ENFIN, and ICPF collectively define the goals and outcomes of the EFMS and develop common descriptions and protocols. The ENFIN and ICPF expert groups facilitate coordination and the exchange of best practices among Member States, operate a data analysis platform, and disseminate forest information in the form of estimates and maps to the European Commission. The EEA further communicates and disseminates the information provided by the Commission through its Forest Information System for Europe (FISE).
- Member States are responsible for collecting and sharing harmonised forest data using their National Forest Inventories (NFIs), ICPF plots, and other monitoring networks. They integrate field observations with remote sensing data to provide comprehensive datasets. National correspondents, serving as liaisons between Member States and the European level, coordinate data preparation, ensure compliance with technical specifications, and facilitate communication.
- The EFMS will be jointly funded by the European Union and Member States. The EU will provide initial setup costs and ongoing support for the central coordination and data analysis platform. Member States will be responsible for funding their national data collection efforts, with additional EU support available for countries establishing new systems.

- Data acquisition is carried out by NFI and ICPF organisations. The data to be utilised in the EFMS are stored in national systems, adhering to the nFIESTA (new Forest Inventory ESTimation and Analysis) standard, which enables Pan-European integration and enhancement of estimates with remote sensing or other auxiliary data sources. ENFIN and ICPF are granted access to the national EFMS data by the Member States, and they use nFIESTA as a module of the mapping and estimation platform to generate forest information.
- ENFIN and ICPF will coordinate the exchange of raw field data with external organizations, which may be particularly relevant for scientific applications, involving JRC as a major actor.
- The proposed governance structure gives high priority to data privacy and security. All data will be anonymised at the source before entering the system. Access rights will be tiered, with raw data accessible only to authorised researchers and policymakers. Public access will be limited to aggregated, non-sensitive information.
- Projections of the current status into future forests are a crucial aspect of the EFMS that will be implemented by Member States in a harmonised manner. This will enable detailed scenario analysis of policy decisions and pathway analysis. Other statistics, such as timber trade and use, will be incorporated into these projections.
- Quality assurance (QA) and quality control (QC) are integral components of the governance structure, applied at multiple stages of the data flow. Feedback loops with key stakeholders including forest owners are also a crucial element, allowing for ongoing improvement and adaptation.

The proposal for a European Forest Monitoring Regulation (EFMR) was published in November 2023. It is currently under negotiation with potential implementation by 2026 and contains unresolved issues like data validation, data protection, and administrative burdens. The EFMR aims for more timely, comprehensive and harmonised forest data across the EU, benefiting various EU policies. Furthermore, it aims to support LULUCF reporting by standardising forest data collection through a framework involving Earth observation and ground-based data mostly collected by National Forest Inventories (NFIs), with shared responsibilities for data quality control between the Commission and Member States. Research underpins forest monitoring methodologies, and while some data requests seem research-oriented, the primary goal is to provide forest information for policymaking. The EFMR's broad scope presents implementation challenges, including unclear methodologies and funding. While this document goes beyond the EFMR by providing a general governance structure of a EFMS, we also give some advices on how the EFMR could be formed to become an effective foundation of the future EFMS (see Conclusions at the end of this document).

With their expertise in forest monitoring, ENFIN and ICP Forests could play a pivotal role in supporting the development of a European Forest Monitoring system. Ground-based measurements and advanced technologies are essential for evidence-based policymaking, necessitating robust data collection and reporting mechanisms to support LULUCF reporting and meeting the EU’s climate targets.

One part of the debate on the EFMR revolves around using legally binding mechanisms for uniform compliance versus non-binding approaches that offer flexibility but may be less effective. This discussion reflects concerns about national sovereignty and the need for cohesive EU-wide environmental policies. Balancing these interests is crucial to addressing environmental challenges

while respecting Member States' autonomy. Furthermore, we recommend a scientific analysis on what “Forest Management Unit” is relevant at EU-level.

Ten key factors to be considered for the successful implementation of a EFMS were identified:

- Define the goals in detail before setting up a monitoring system.
- Focus on forest monitoring instead of other political agendas by the EU.
- Use statistical estimates as backbone of the EFMS.
- Make use of existing expertise from ENFIN as well as PathFinder findings in a stepwise bottom-up process.
- Put the focus on forest information instead of plot data.
- Avoid inadequate proxies derived from remote sensing.
- Data privacy and sensitivity concerns must be addressed explicitly.
- Use realistic estimations of costs.
- Address support in expertise and funds to ensure equal and high-quality standards in every Member State
- Promote increased interaction between key actors.

2. Introduction

2.1 Goals of this deliverable

During the last decades, several forest monitoring and reporting requirements have been established globally (e.g. GFRA) and for Europe (e.g. SoEF) including mandatory and voluntary systems. Some of them were put in place using existing structures, for others the existing structures had to be adjusted. In recent years a couple of additional forest or forest-related reporting obligations have been introduced by the EU. Now the question arises, if the existing structures can support all these systems adequately or if there is a need to develop new structures and what they could look like.

Based on historical experiences and structures of existing large-scale forest monitoring systems and consideration of essential prerequisites, a governance structure for a European Forest Monitoring System (EFMS) is proposed in Chapter 3. The main parts are:

- to discuss and specify the goals of the EFMS,
- the general approach including possible institutional settings,
- to define responsibilities, flows of data, work and interactions,
- and finally look at the financial implications

2.2 Historical developments

The first attempt to develop a common pan-European forest monitoring system was triggered by a trans-national issue: the effect of transboundary air pollution on forests.

In 1979 the United Convention on Long-range Transboundary Air Pollution (formerly CLTRAP, today Air Convention) was signed and now involve 51 parties (UNECE 2019). Its Working Group on Effects (WGE) includes six International Co-operative Programs and one of these is ICP Forests, arguably the first pan-European international monitoring program which today include 42 Countries in the UNECE region. ICP Forests was formally launched by the Executive Body (EB) of the Air Convention in July 1985 (ICP Forests 1994). The EB also established a Program Task Force (TF) with Germany as Lead Country. The structure of the ICP Forests was, and still is, based on National Focal Centres, i.e. institutions designated by the signatory Country to collect and submit data and information to the Programme Co-ordination Centre, now at Thünen Institut, Eberswalde, Germany. The structure of

the ICP Forests is supplemented by Expert Panels, Groups and Committees (ICP Forests 2011a) which deal with technical and scientific matters, including the continuous development of the ICP Forests Manual (ICP Forests 2011b) (See Figure 1). All participating countries are invited to join these groups. The decision body of the ICP Forests is the TF which has been held annually since October 1985.

In 1986 the European Commission published the EC Regulation 3528/86. The objective of such a regulation was to "establish, based on common methods, a periodic inventory of damage caused to forests...; — establish or extend, in a coordinated and harmonious way, the network of observation plots required to draw up that inventory". The EC Regulation 3528/86 was the basis of a "European Union Scheme on the Protection of Forests against Atmospheric Pollution" (Vel, 1996). Such a scheme includes several Regulations dealing with the methodologies for the Level I survey (1696/87) and the concept of "Intensive monitoring" and its methods (2157/92; 1091/94). Related Regulations included information management, soil inventory and foliar analysis on Level I, meteorological, deposition and soil solution on Level II (Cenni & Ferretti 1998). At the EC Level Member States were represented in the Standing Forestry Committee, and - as a signatory party of the Air Convention - the EC was part of the ICP Forests TF.

ICP Forests and the European Union closely cooperated towards methodological harmonisation (ICP Forests methods were published on the Official Journal of the EU) and until 2003 had a joint reporting system (ICP Forests 2011c). Such a cooperation was essential: the multi-level monitoring system envisioned by the ICP Forests (ICP Forests 2011b) would have been impossible without the co-financing of the EC. This has led to important political achievements, including the MCPFE Resolutions in Strasbourg 1990 (S1) and Helsinki 1993 (H1) and to a continuous, still unrivalled pan-European monitoring system that contributes data to science and reporting (Ferretti et al. 2024).

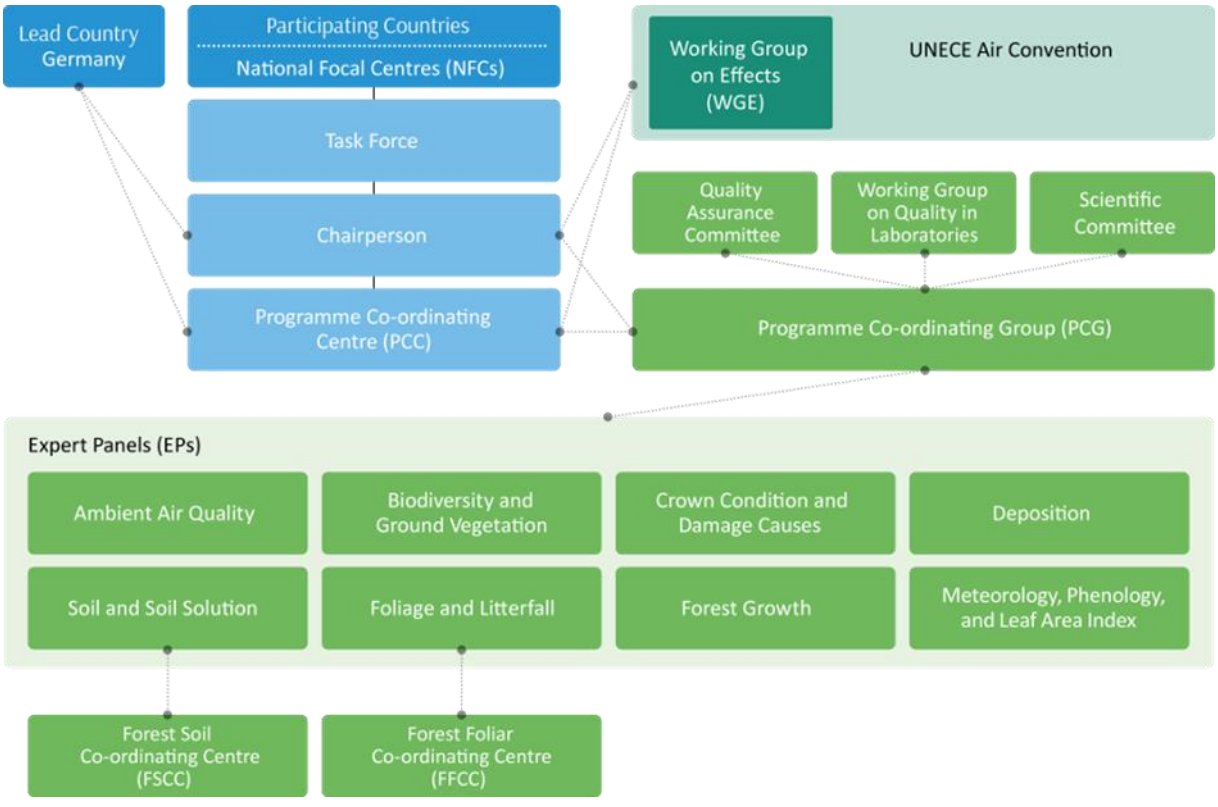

Figure 1: Governance structure of ICP Forests (source: http://icp-forests.net/page/bodies-structure).

The governance structure of the ICP Forests is a combination of top-down and bottom-up approaches. Top-down: Participating Countries are members (with the right to vote) of the Task Force of the ICP Forests, the only body entitled to make decisions on official reports, methods and manuals. The Chairman of the Task Force is nominated by the Lead Country (Germany) since the foundation of ICP forest and works in contact with it, PCC and the UNECE Air Convention Bodies. Bottom-up: Expert Panels and Committees are responsible for methods, manuals, data quality procedures and checks that are ultimately submitted to the Task Force for approval. The PCC is responsible for the co-ordination, data infrastructure (data storage, validation, provision), editing manuals and reporting (Technical Reports, Briefs) which are subject to approval by the Task Force. Participating Countries are responsible for training, data collection and submission to PCC.

National Forest Inventories have built the backbone of national and international forest reporting since the beginning of the Forest Resources Assessment (FRA) in the 1960s. Meanwhile, out of the 27 EU Member States, 23 have an ongoing National Forest Inventory (NFI). They all supply forest data and information at national and sub-national levels since up to 105 years. In 2003 the European National Forest Inventory Network (ENFIN) was founded with the main aim to establish pathways for common reporting. Since that time the harmonisation work of ENFIN has produced commonly accepted and operational reference definitions and solutions to bridge the gap between national and reference definitions for many forest indicators as an order from the European Commission (JRC). These methods can be found in peer-reviewed papers and project reports (see https://www.enfin.info/index.php/publications and https://www.enfin.info/index.php/projects). ENFIN's structure includes a chair, a vice – chair, a Steering group and all Members (see Figure 2) who signed a Memorandum of Understanding defining the goals of the network. Annual meetings of all members and several Steering Group meetings per year build the basis of the networking activities.

Figure 2: Member countries of ENFIN in 2024 (source: https://www.enfin.info/index.php/members)

2.3 Recent developments in European Forest Monitoring

The lead up to the policy process related to the EFMR was initiated with the adoption of the New EU Forest Strategy for 2030 in July 2021. It included a commitment to develop a legislative proposal for an EU-wide Forest Observation, Reporting, and Data Collection framework. The European Commission launched a public consultation on the Forest Monitoring and Strategic Plans initiative, seeking input from stakeholders in November 2022. In the Spring of 2023, the Commission conducted targeted stakeholder consultations, including workshops and meetings with various groups such as Member States, industry representatives, and NGOs. An impact assessment was initiated to evaluate different policy options for the Forest Monitoring Framework. The European Commission published a proposal for the European Forest Monitoring Regulation on November 22, 2023. The proposal is currently going through the ordinary legislative procedure, involving negotiations between the European Parliament and the Council of the EU. The potential implementation of the EFMR is expected by 2026, depending on the outcome of the legislative process.

One year before its publication, meetings on European Forest Monitoring organised by the Czech, followed by the Swedish and then the Spanish presidencies were held. Subsequently, the Belgian Presidency established the Ad hoc Working Party on Forest Monitoring (AHWP FM) in January 2024 to carry out preparatory work. To date, the AHWP FM has held seven working party meetings to

examine the proposal in detail. The Belgian Presidency has adopted a "clustering approach" to analyse the proposal step-by-step, starting with principles and generalities, progressing through details, and ending with implementation implications. Eight clusters have been identified for this analysis: Forest Monitoring System, Planning, Identification system, Collection framework, Sharing framework, Exchange and use, Data collected, and Implementation. The multidisciplinary format of the AHWP FM, providing both forestry and environmental expertise, has proven particularly useful in examining the proposal. Discussions have been technical and intense, with Member States generally sharing the main objectives of the proposal.

However, many questions and concerns remain unresolved, and key issues under discussion include the definitions of 'forests' and 'forest unit', the compatibility of remote sensing and in-situ data, the validation of forest health (defoliation) data, the limited incorporation of existing monitoring systems, data protection issues, harmonisation of data at the EU level, administrative burden and costs for Member States, and concerns about voluntary provisions and delegated/implementing acts.

The first full examination cycle of the proposal was completed during the summer of 2024 under the Hungarian Presidency with a focus on cluster 7 (data collected) and its three lists of forest indicators. While there is general support for improved forest monitoring, many concerns of the Member States as well as technical details have not been addressed yet. The process is still in the early stages of examination and negotiation within the Council, with no formal positions adopted by the European Parliament committees at this time.

2.3.1 Data responsibilities of the EFMR

In general, the three annexes foresee different responsibilities for the data collection. In indicator listed in annex I are collected by the commission. However, Member States can opt out of using the Commission's standardised data collection service and instead contribute their data to the monitoring system. If opting out, Member States must collect data themselves according to the technical specifications in the regulation and annually assess the data quality. The indicators within Annex II have to be collected by the Member States. In Annex III the collection of additional forest data is listed. This list is subject to a stepwise approach that will be implemented through delegated acts.

2.3.2 Linkages and synergies with existing reporting schemes

The regulation foresees synergies with existing reporting systems such as the LULUCF regulations and the Forest Information System for Europe (FISE). It aims to integrate and harmonise data from various sources, including Earth Observation tools as well as National Forest Inventories and monitoring systems, to provide a comprehensive picture of the state and condition of forests within the Union.

The EFMR calls for a new era regarding the collection of forest variables. It may offer substantial benefits to various EU forest-related policies, including those without explicit formal reporting obligations. The EFMR expects to provide more timely, comprehensive, and harmonised data on forest conditions across the EU using advanced technologies such as remote sensing, and forest information from NFIs and other existing forest monitoring systems (EC 2023a). By doing so, it expects to enhance policy design, implementation, and impact assessment across multiple forest-related policy areas. The EFMR is mentioned and aligns with the EU Forest Strategy. It supports sustainable forest management, biodiversity protection, and climate change mitigation/adaptation by supplying comprehensive data that facilitates tracking progress towards the Strategy's goals. The EFMR aims to support several major EU forest-related policies, as shown in Tables 1 and 2. The EU Biodiversity Strategy 2030 to support the assessment of biodiversity targets and old-growth forest

protection (EC 2020); the EU Climate Policy/European Climate Law to enhance the LULUCF reporting on forest carbon stocks (EU 2021a); the Common Agricultural Policy to inform forestry measures and environmental impacts (EU 2021b); the EU Bioeconomy Strategy to support sustainable forest-based bioeconomy development (EC 2018); or the Renewable Energy Directive to provide data on forest biomass resources and sustainability (EU 2023). However, this complexity comes with some challenges. The integration of advanced technologies for data collection requires significant investment and coordination among Member States, which could pose implementation challenges.

Table 1: Main legally binding forest-related reporting.

Forest-related policy	**Main topic**	**Forest variables**	**Reference**
Habitats Directive	Conservation status of habitats and species (assessed as favourable, unfavourable-inadequate, unfavourable-bad, or unknown)	Range, area covered by habitat, structure and functions, future prospects, population size and trend for species, habitat for the species, pressures and threats, conservation measures	Directive 92/43/EEC, Article 17
Nature Restoration Law	Forest ecosystem restoration indicators	Legally binding: Abundance of common forest birds and increasing trend in forest ecosystem indicators at the national level for at least six out of seven specified forest ecosystem variables: • Standing deadwood • Lying deadwood • Share of forests with uneven-aged structure • Forest connectivity • Stock of organic carbon Share of forests dominated by native tree species Tree species diversity	Regulation (EU) 2022/869
Joint Forest Sector Questionnaire (JFSQ)	Production and trade of wood and wood products	Removals, imports, and exports of roundwood and wood products, fuelwood, pulpwood, wood pellets, sawn wood, wood-based panels, pulp, paper, paperboard, secondary wood and paper products	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Forests,_forestry_and_logging https://unece.org/forests/jfsq
Land Use, Land Use Change and	Land use categories	Forest land use categories, and changes, removals,	Regulation (EU) 2018/841

Forestry (LULUCF) Regulation	GHG emissions and removals from forest management Carbon stored in harvested wood products	carbon pools (biomass, deadwood, soil, litter), harvested wood	
EU Regulation on Deforestation-free products (EUDR)	Proof of deforestation-free sourcing	Geolocation data of land where products were produced Information on suppliers and customers	Regulation (EU) 2023/1115
Renewable Energy Directive RED II	Overall EU target for Renewable Energy Sources consumption by 2030 raised to 32%	- Forest area and resources data - Sustainability criteria compliance for forest biomass - Forest management practices information - GHG emissions reduction data for biomass-based plants	RED II Legislation
Renewable Energy Directive RED III	Increased overall EU target for Renewable Energy Sources consumption by 2030 to at least 42.5% (with an aspirational target of 45%)	- Sustainability criteria compliance for forest biomass - Data on biomass sourcing and origin - Information on forest management practices - Greenhouse gas emissions reduction data	COM/2021/557 final
Corporate Sustainability Reporting Directive (CSRD)	Energy-related emissions (indirectly affects forest-based products)	GHG emission savings from biofuels and biomass fuels Carbon stock changes in forests Impact on biodiversity and ecosystems Indirect land use change (ILUC) impacts |	Directive (EU) 2022/2464
National Emission Ceilings Directive	Forests and Woodlands, negative impacts of air pollution upon ecosystems	Soil acidity and nutrients loss, Soil nitrogen status and balance Biodiversity loss Ozone damage to vegetation growth and biodiversity	Directive (EU) 2016/2284 https://icp-forests.net/

Table 2: Main non-legally binding forest-related reporting.

Forest-related policy	Main topic	Data/indicator	Reference legislation
EU Forest Strategy for 2030	Carbon stocks Biodiversity metrics Forest health and resilience Socio-economic functions of forests	Forest area	COM(2021) 572 final
EU Biodiversity Strategy for 2030	Forest quality and quantity	Forest connectivity Forest fragmentation Biodiversity indicators Protected forest areas Forest restoration areas	COM(2020) 380 final
European Forest Accounts (EFA)	Forest accounts	Forest area (wooded land) Timber volume (stocks and flows) Economic variables (output, intermediate consumption, gross value added) Employment data Carbon stocks in forests and harvested wood products	Eurostat EFA
Forest Europe	Sustainable Forest Management	Forest area, timber volume, economic variables, employment data, biodiversity, forest health and vitality	Forest Europe Process
Copernicus Climate Change Service (C3S)	Climate monitoring and forecasting	Fire weather indices Vegetation stress Historical fire danger indices	Copernicus Climate Change Service
Global Forest Resources assessments	Global forest resources monitoring	Forest area Forest type Forest ownership Forest use Forest health and vitality Carbon stock Biodiversity	FAO Global Forest Resources Assessment
UNECE Air Convention	Forest ecosystem status and changes	Forest health Forest biodiversity Forest growth Forest Phenology and LAI Forest soil and soil solution Forest foliar and litterfall Air Pollution Atmospheric deposition Meteorology	https://icp-forests.net/

However, only a few of these are explicitly stated to have formal reporting obligations. These are the Joint Forest Sector Questionnaire (JFSQ), the Land Use, Land Use Change and Forestry (LULUCF), EU Regulation on Deforestation-free products (EUDR) Regulation, the Habitats Directives, the Renewable Energy Directives (RED II and RED III), and the Corporate Sustainability Reporting Directive (CSRD). Table 1 summarises which indicators are reported under these policies.

The LULUCF Regulation, which mandates extensive reporting on forest-related activities and carbon stocks, is expected to benefit significantly from the proposed European Forest Monitoring Regulation (EFMR). Both regulations report on forest area, carbon stocks, and forest health, ensuring consistency and reliability in data collection. Enhanced EFM could aid in tracking progress towards the LULUCF sector's contribution to climate neutrality by 2035 and net negative emissions thereafter.

The EFMR would help simplify complex accounting rules, such as the Forest Reference Level setting process, and address gaps in national monitoring systems. Remote sensing data, obtained from aerial or satellite imagery including Earth observation tools from programs like Copernicus, offer extensive spatial coverage and can capture various forest attributes across large areas. The EFMR proposes the use of advanced technologies to, i.e., ensure that data on carbon stocks and fluxes are more accurate, enabling Member States to report LULUCF emissions and removals more precisely.

2.4 Recent ENFIN developments

Up until now, ENFIN has been a network comprised of European NFIs and not a formal legal entity. In recent years, there have been aspirations to convert ENFIN into an official legal entity in order to strengthen its efforts to support EFM. These endeavours will lead to the official founding of the ENFIN Association governed under French law in October, in which organisations in charge of the respective NFI can be members. Other parties which can contribute to ENFIN association's goals may become partners. Due to the support from Member States and through the structural change, ENFIN will have a better legal and an overall more official standing to deliver its channelled expertise to stakeholders which includes consulting for the development of a European Forest Monitoring System (EFMS). Furthermore, this step will make it easier for the European Commission to involve ENFIN in projects and discussions. During the first years an overlap phase in which both Networks (ENFIN and ENFIN association) exist is foreseen.

2.5 Debating the legally binding status of the EFM

A key debate surrounding the proposed EFMR and EU forest governance, generally, captures a central tension between the application of legally binding mechanisms as opposed to non-legally binding alternatives. This tension strikes at the heart of concerns, held by some Member States, regarding issues of sovereignty and subsidiarity, against the need to improve coherency and integration of forest and environmental policy across all sectors and political levels within the EU (Edwards & Kleinschmit 2012).

The EU's legally binding mechanisms, by definition, establish mandatory compliance with established rules or standards through legal or regulatory means. The EFMR's legally binding status intends to ensure a uniform approach to forest monitoring across all Member States, with the aim to monitor and respond with appropriate management and policy, resulting in better-managed forests through a more informed and coherent data framework. Proponents emphasise the necessity for greater forest data harmonisation across all EU Member States as essential to meet key environmental and climate targets (Onida 2020). Some argue further that without such uniformity, individual Member States may prioritise short-term economic gains over long-term sustainability (Baycheva-Merger &

Sotirov 2020), leading to disparate and potentially conflicting policies that undermine collective EU environmental goals.

In contrast, proponents of non-legally binding approaches, such as guidelines, action plans, or voluntary agreements, argue that they offer flexibility and adaptability (Onida 2020). Such measures allow Member States to tailor their forest management practices to local conditions and priorities, potentially fostering innovation and local engagement in forest conservation (Baycheva-Merger & Sotirov 2020). Some Member States and their relevant forest authorities argue that they have established experience with NFI data and fear that the EFMR sets mandatory obligations that undermine this existing knowledge, while also unnecessarily doubling costs and effort. However, non-binding measures have historically been seen as weak forms of governance within the EU, often insufficient to counteract the pressures from other policy areas such as agriculture or rural development (Edwards & Kleinschmit 2012).

Existing literature observes the contestation surrounding EU forest policy integration, highlighting the complex interplay of national interests and EU-wide priorities. Baycheva-Merger & Sotirov (2020) show that there is a reluctance of many Member States to share forest data, fearing loss of sovereignty and control over their strategic natural resources. Onida (2020) deliberates on accusations that the EU does not have legal competency over forest governance, demonstrating how a number of decisions in the last five decades at the EU level have set mandatory rules for MS' management of their forests. Nonetheless, this resistance underscores a significant challenge: aligning national priorities with broader EU forest and environmental policy ambitions.

Central to this debate is the principle of subsidiarity, which holds that the EU should only act when objectives cannot be sufficiently achieved by individual states (Edwards & Kleinschmit 2012). This principle is particularly potent in areas like forest governance, where local knowledge and conditions are paramount (Onida 2020). However, as current environmental challenges transcend national borders, there is a compelling argument for more centralised oversight to ensure that local actions do not undermine EU and International environmental and climate policy goals. We observe the limitations of non-legally binding mechanisms and the relevance of the need for subsidiarity in the case of the EFMR to tackle problems that require a synchronised response across all European Member States

2.6 Providers and Users

Since the early 2000s, in response to political developments in European forest and environmental governance, there has been an increase in diversified forest information requirements (Onida 2020). Member States and European scientific bodies have concentrated their efforts on developing the quantity of forest information, as well as improving the quality and harmonisation of data collection and reporting (e.g., ENFIN). It is the aim of the European Forest Monitoring System (EFMS) to further harmonise this data - ensuring that providers deliver necessary forest data to a variety of environmental services and users across the EU.

The stakeholders of forest data and information can be clustered into three categories: pure users of data, pure providers of data and providers of data who also use data.

Among the most widely recognised sources of expert-based forest data and ultimately forest information are monitoring systems such as NFIs and the ICP Forests. Their monitoring systems are customised to the specific data requirements such as carbon storage, the relation between growth and harvest rates or deadwood for biodiversity policies, etc.

The information provided by NFIs is typically used to guide and support EU, national and sub-national decision and policymaking processes in forestry as well as related sectors. There are a number of stakeholders beyond political decision makers interested in the information of monitoring systems. These include land-owner organisations that have a general interest in the status of forests, but in general they cannot directly use large scale statistical estimates for their management decisions as the information is not customised to their land. Therefore, they have to base them on their own management inventories. Within some EU countries NFIs or other national organisations provide support for these management inventories.

Forest-based industries might use this information as well to anticipate market developments regarding their raw materials. Certification organisations need the data and information to include them into their certification systems. Environmental NGOs use forest information to propose changes in policymaking and management.

Furthermore, research institutions, universities and certain environmental NGOs use forest information and process them further to conduct research projects creating additional information. Finally, International organisations such as the UNECE, FAO and Forest Europe use data provided to them specific reporting formats. These data are then aggregated and interpreted by national experts, which also makes these organisations data and information providers.

In recent years there have been developments to produce forest data through other means than design-based ground sampling. These model-based data mostly rely on remote sensing. Precision and accuracy are much lower than those of design-based approaches. The resulting uncertainties might include (unknown) biases and can thus create difficulties when directly used as basis for policymaking (for more detail see the following section). Examples for such data providers are Global Forest Watch, Climate Trace, Google Environmental Insights Explorer.

Table 3 shows a non-exhaustive list of stakeholder categories and organisations while highlighting if they fall under the category of data providers, data users or data providers who also use data, excluding those sources mentioned in the prior paragraph.

Table 3: Identified stakeholder categories and examples for their related authorities / organisations. Data providers in italic and users underlined, some organisations are providers and users

Stakeholder Categories	**Represented Authorities / Organisations**
European/national research and academic institutions	*NFIs, ICP Forests, Universities, EFI, BFW, LUKE, NIBIO, CSIC, GOZDIS, IGN*
European/National institutions	European Commission (e.g. DG Clima, DG Agri, DG environment, *Eurostat, JRC*) and other agencies (e.g. *EEA*), Ministries and MS administrations responsible for forestry
International/pan-European organisations	*UNECE/FAO, Forest Europe*
European public and private forest owner associations and State Forest management organisations (SFMOs)	EUSTAFOR, CEPF, MTK, COPA-COGECA, ELO
Environmental non-governmental organisations	*BirdLife international, WWF*, FERN, CDP
Forest-based industries	FTP, CEI-Bois, EPF, EFIC, CEPI

Certification organisation	FSC, PEFC, national Carbon certification organisations
Financial: investors, banking and insurers	GCF, GIIN, Dasos Capital; EIB, EBRD; AXA and Allianz

2.7 Estimations and predictions - Accuracy as a part of the quality management

Unbiasedness is of highest importance when reporting to several mandatory policy processes. Possible discrepancies arising from the sole use of model-based predictions will very likely negatively affect the reliability e.g., of the overall greenhouse gas inventory and compliance with climate targets.

Adequate resources, capacity building, and effective coordination among the European Commission and Member States will be necessary to address these challenges of quality management. The success of the EFMR depends on overcoming significant technical, administrative, and coordination challenges. Ensuring robust, reliable, and effectively integrated data collection and reporting mechanisms is crucial for maintaining the integrity of the greenhouse gas inventory and achieving climate targets. Data from the EFMR feeds into the Forest Information System for Europe (FISE), supporting comprehensive LULUCF reporting.

Relying on advanced technologies, such as mapping of carbon storage derived from satellite data, introduces risks related to data integrity, and the need for continuous technological upgrades. Accurate and precise estimates of forest attributes are crucial for successful policymaking. Accuracy and precision also compromise timeliness, especially in the case of attributes describing changes in forests, such as forest areas damaged by insects or carbon stock change. Forest inventory data, collected through ground-based measurements, can provide detailed and accurate information on forest structure and composition. Most national-level forest inventories are grounded in probability sampling theory. They provide unbiased estimates of forest attributes based on sample plots within the forest. These design-based methods are robust and straightforward.

Another approach used by inventories regards model-based approaches that rely on statistical models to predict forest attributes based on auxiliary data, such as remote sensing techniques. These models can capture complex relationships between observed data and forest characteristics, allowing for detailed and spatially explicit predictions. However, model-based methods depend heavily on the validity of the model assumptions and the quality of the auxiliary data. Aggregating model-based predictions, also known as synthetic or pixel counting estimates, for example for whole countries, can result in a considerable bias (Ceccherini et al. 2020). Basing policy decisions on this kind of estimates, can have unintended and negative effects.

Therefore, PathFinder aims to complement probability samples of field plots (design-based) with the prediction of forest attributes from remote sensing data (model-based). This integrated method, known as model-assisted approach (Särndal et al. 1992) can significantly enhance the accuracy and precision of forest estimates by reducing sampling errors and enhancing spatial coverage. This allows leveraging the strengths of both approaches, utilising forest inventory data and remote sensing data to provide comprehensive and reliable forest metrics. A good overview of such estimators can be found in Mandallaz (2013), Stahl et al. (2016), and Hill et al. (2021).

3. Governance Structure

3.1 Defining Forest Monitoring

Before a Governance Structure can be proposed, a clear definition of what is meant by forest monitoring, its scope, and its use is needed. So far, there are different definitions in use which cannot be easily unified:

- On its webpage (https://www.enfin.info/), ENFIN defines forest monitoring as a comprehensive system focused on tracking changes in forests over time. The approach emphasises the use of NFIs as a primary source of forest information, incorporating remote sensing technologies, harmonising data and methods across European countries, and providing detailed, accurate, and comparable information on forest ecosystems (https://www.enfin.info/index.php/aktuell-2).
- Among the many available definitions, in ICP Forests defines forest monitoring as "an organized time series of measurements of defined physical/chemical/biological variables over a defined forest entity and designed to provide defensible answers to questions about its status and changes" (Ferretti, 2013; see also Table 1.1 therein). Beyond these traditional, descriptive objectives, the investigation of cause–effect can also be accommodated in monitoring systems (Olsen and Schreuder, 1997)
- The EFMR defines forest monitoring as an EU-wide integrated system aimed at providing open access to detailed, accurate, regular, and timely information on the condition and management of EU forests (EC 2023). The key aspects include the approach, combining remote sensing and ground-based data collection, the focus on policy-relevant parameters like climate change, biodiversity, forest health, and invasive species, the establishment of a harmonised and standardised data collection and sharing framework, and encouraging the development of long-term forest plans by Member States.

Although there are several similarities between the definitions and approaches, the EFMR is more explicitly tied to policy objectives and priorities. The EU's proposal includes a specific framework for data sharing, which is not as prominent in neither ICP Forests nor ENFIN's approaches but is developed within PathFinder. Finally, the EU regulation encourages Member States to develop long-term forest plans, which is not a focus of ENFIN and ICP Forests.

3.2 Discussing the goals for EFM

As captured in the New Forest Strategy for 2030, forests have an important role in various fields such as the economy and society, mitigating climate change and reversing biodiversity loss (EC 2021). This multifunctional role of forests has to be adequately addressed when defining goals for forest monitoring. The following paragraphs discuss the goals as they are proposed within the EFMR and discuss some aspects like the role of research and the links to data policy in more detail. As an example, the needs for LULUCF reporting are described. Finally, the pros and cons of a holistic, i.e. considering all potential uses for forest information including the local forest management level versus a more focused approach, i.e. especially concentrating on policymaking, are discussed.

3.2.1 Goals of the EFMR

The European Commission describes the main goals as follows (EC 2024):

- Efficient and effective policymaking and implementation
- New Business opportunities

- Disaster prevention, preparedness and response

Additionally, examples are given encompassing protecting primary and old-growth forests, restoration, adaptive forest management, incentives for forest owners and managers, sustainable use of bioenergy. All these examples are linked to existing EU regulations. As identified by Di Marzo (et al. 2023), there are numerous forest-related policies ranging from EU Forest Strategies over the Nature Restoration Law to the Bioeconomy Strategy within the EU. Most of these policies require monitoring data which results in a high complexity of the demands for these data. Thus, the complexity of the demand for forest data increased with the increasing number of forest-related policies. The EC also gives an overview of the main beneficiaries: Member States, forest owners, forest industry and the European Commission.

The proposed regulation establishes a forest data collection framework that includes both standardised and harmonised data. Annex I presents data primarily collected by the Commission via Earth observation (e.g., Copernicus satellites) called standardised data. Annex II describes the data collected at MS level from their national surveys and monitoring systems, such as the NFIs. Data harmonisation is ensured by requiring Member States to share plot-level and aggregated forest data according to common descriptions and methods.

When developing a data collection framework, certain attributes are of high relevance. This includes amongst others the report frequency and the data quality control. Reporting frequency varies by data type, ranging from bi-weekly to every 5-6 years (Annexes I and II). Reporting is to be conducted regularly.

Thus, the primary goals of the proposed regulation are to ensure high-quality, comparable forest data across the EU, support voluntary integrated long-term planning by Member States, and enhance forest resilience against climate change and other disturbances. The regulation aims to provide accurate and timely data to support EU policy objectives related to climate change, biodiversity, and disaster risk management (EC 2023a, EC 2023b).

3.2.2 Monitoring and research

Research and monitoring are strongly intertwined. First, different research disciplines use monitoring data to test hypotheses, explain and describe relationships between different factors. Second, there is continuous research focusing on the development of monitoring approaches and methods. The outcomes of both – monitoring and research aim to support decision making by reducing uncertainty. The main role of forest monitoring is to provide sound statistical estimates of status and changes of forest ecosystems. Forest research is much broader, but when coupled with monitoring it often investigates cause effect or driver response relationships. Therefore, monitoring for research purposes often needs a high level of detail. This leads to a trade-off between statistical representativity and the level of detail, mostly driven by additional costs. This fact is mirrored in the different levels of ICP forests and integrated monitoring network (Level I, II and III). The main interlinkages between forest research and forest monitoring can be summarised as follows:

- Forest research includes statistical investigations on optimising the quality of forest monitoring:
  Research activities represent the basis for establishing and implementing monitoring methodologies. In the field of forest monitoring, literature widely exists from classical handbooks on sampling theory within the forests up to recent findings to optimally integrate remote sensing (RS) and other auxiliary variables into the estimation system (e.g. Stahl et al. (2016)).

- Research orientated long term monitoring to address cause effect relationships: Statistical sampling of NFIs can to some extent fulfil research questions related to forest biodiversity and forest resilience as well. However, the level of detail and the range of attributes is restricted mainly by high costs for the NFIs. Therefore, less intensive sampling in space is also necessary to meet the data requests necessary for more intensive analyses (Ferretti at al. 2024). On the other hand, these monitoring systems often do not fulfil the statistical requirements necessary for sound statistical estimates

A well thought through combination of both is essential for an EFMS. However, research should never jeopardize the monitoring systems: for the development of remote sensing products plot coordinates are sometimes essential but cannot be openly accessible. For instance, there is a high risk that management decisions might change if the plot coordinates are known to the respective forest manager, thus impairing the representativity and unbiasedness of the monitoring system (Schadauer et al. 2024a).

3.2.3 Analysis of Temporal and Spatial data needs for LULUCF

As outlined in Subsection 3.1.1, there are numerous EU forest-related policies in need of data from monitoring systems. As not all these policies can be described, the LULUCF regulation is used as example. Forest monitoring aims to provide a broad overview of forest conditions and trends over large areas and over time. Monitoring relies on a systematic and consistent collection of data from numerous plots to detect changes over time and support policy. The EFMR asks for forest data at the monitoring site level for several forest variables under its Annex II: growing stock volume, net annual increment, stand structure, tree species composition and richness, European Forest Type and deadwood (EC 2023b). Such plot data serve distinct purposes in forest research where it is used to investigate specific scientific questions, such as understanding forest dynamics, species interactions, and ecological processes. These data are often collected with high precision and detail, focusing on a limited number of plots to gather in-depth information.

The EFMR encompasses a wide range of data types with varying spatial resolutions and collection frequencies. High-resolution data (10m or finer) are generally collected more frequently, often annually or even weekly for fire-related information. Medium-resolution data have diverse collection frequencies, while national and regional level data are typically collected every 5 years.

A notable difference between the LULUCF regulation and the EFMR monitoring is the latter's focus on forests. LULUCF requires annual reporting of greenhouse gas emissions and removals, with a focus on long-term trends and changes in carbon stocks. The spatial resolution for LULUCF reporting is generally at the national or regional level aggregated for the 6 specific land categories: forest land, cropland, grassland, wetlands, settlements, and other land.

The EFMR has the potential to significantly support LULUCF reporting as it aims to provide comprehensive, high-quality monitoring of EU forests, which line up with the data needs of LULUCF reporting. The forest data that could potentially be used directly for reporting purposes comprises of forest area, growing stock volume, net annual Increment, deadwood, tree species composition, and removals. However, it is important to mention, that design-based approaches for the estimation are used and not model-based predictions, which would compromise the time-series of LULUCF reporting that aims at long-term trends.

Further, the methods for carbon stock measurement and quantification of greenhouse gas emissions and removals are not defined in the EFMR, which could lead to inconsistencies with LULUCF requirements. LULUCF requires annual reporting of emissions and removals, with a shift towards

more spatially explicit data (IPCC Approach 3) for land use conversions. The EFMR aims to provide frequent updates using a combination of remote sensing and ground-based data, which could potentially meet LULUCF's temporal requirements. However, the methods used must undergo the quality assurance procedures as mentioned in subsection 2.6. These aspects could then enhance the accuracy and consistency of carbon stock and land use change data, which are crucial for LULUCF reporting. Without the inclusion of quality assurance procedures, the reporting will suffer from inconsistencies and a lack of transparency.

3.2.4 Data policy and data platforms

The EFMR is undeniably linked to data, data collection and to some extent to data policy. It aims to strike a balance between comprehensive data collection, public accessibility, and data sensitivity concerns. It proposes to provide a framework for harmonised data collection across the EU while allowing some flexibility for Member States in their data collection methods.

The data-sharing framework acknowledges the sensitivity of certain data, particularly regarding the geographically explicit location of monitoring sites. Sharing precise monitoring site locations is subject to the establishment of safeguards, as mentioned in Article 9(2). The Commission is empowered to adopt implementing acts to establish confidentiality-preserving safeguards for including geographically explicit location information in data storage and exchange systems.

As proposed, the EFMR has plot data sensitivity and data privacy concerns, particularly regarding the specific locations of monitoring sites. This could be a problem for data collection by Member States. Many NFIs currently treat the precise locations of monitoring plots as confidential information. Member States may be reluctant to share geographically explicit plot locations due to privacy concerns for private forest owners or sensitive ecological information, and most importantly: because of the concern that revealing the locations of permanent monitoring sites would jeopardize the reliability of the whole monitoring system as described above (Schadauer et al. 2024a). There could be legal or administrative barriers in some countries for sharing such detailed geospatial data.

NFIs collect plot data, yet the need of plot data for users of national monitoring systems is very untypical. The ministries in charge do not request plot data, as they are interested in results and information at different spatial scales.

Plot data represent only small, areas within a forest, and are typically located in a relatively sparse network. Consequently, plot-level data do not provide a comprehensive picture of the spatial structure of forests, rendering them inadequate for extensive forest monitoring (Breidenbach et al. 2022; Fassnacht et al., 2023). Remote sensing technologies, which rely on ground-truth data for validation, face misalignment issues due to the discrepancy between the small scale of plot-level data and the broader scale of remote sensing data. This misalignment can skew validation processes and reduce their reliability, particularly when validating spatially continuous maps derived from remote sensing (McRoberts et al., 2016; Cushman et al., 2023; Hauglin et al., 2021).

From a forest management perspective, decisions are typically made at the forest stand or landscape level, not at the individual plot level. Therefore, plot-level data are less relevant for operative forest management decisions as they do not encompass the necessary spatial breadth required for effective management strategies (Häme et al., 2013). Their specific and limited scope can miss changes occurring beyond their narrow confines, making it challenging to track long-term trends and changes in forest conditions (Kangas et al., 2018).

There could be several reasons why NFI plot data are requested within the EFMR.

1. The proposal foresees a recalculation of results provided by the NFIs.
2. The proposal foresees the use of data for producing and validating maps on its own.
3. The proposal foresees the need to do further research on its own.

Member States would most likely interpret the first reason as mistrust. For the second reason, ENFIN has proven its capacity to work on European-wide mapping, in case such mapping is needed (Miettinen et al. 2024). The advantage of maps produced by experts from Member States is that they are derived including national expertise and transparent procedures will support the acceptance (Baycheva-Merger & Sotirov 2020).

There are ways deal with the sensitive topic of plot data. For instance, ENFIN has developed two data sharing and estimation platforms: eForest (still in use) with the support of the European Commission and nFiesta within two European Projects (Diabolo and ongoing in Pathfinder) (Lanz et al. 2019). On one hand these systems allow for quality management during the upload of the data. Secondly, the file systems and the software are ready for estimations across different sampling schemes. Finally, the inclusion of the use of auxiliary data like maps from EO or other data sources.

Within Annex I of the EFMR, the intensive use of maps is explicitly described. However, how they are validated is not described but it is a crucial part of an EFM (e.g. Schadauer et al. 2024b). Without knowing the precision and biases of map products they should not be used for any kind of decision-making. This could easily be handled by ENFIN to establish a validation system for maps. This validation would guarantee an independent and high scientific level leading to acceptance of the MS and evidence-based policy at the European level.

3.2.5 From Data to Information

As the main goal of EFM is information on the European level to be used for policymaking, data are not an essential product to be envisaged. This is primarily true for plot data. Moreover, the raw output from the estimation is often not easily interpreted correctly and thus needs explanations from experts to be included into reports. Separating a system between data and information very often leads to misinterpretations. A transparent reporting system must include people from the data assessment, from the estimation process and finally inputs from users of the information to ensure sound and comprehensive reporting.

3.2.6 The forest management level

Forest monitoring systems sometimes also include the management level, meaning that forest managers can directly include the information into their management decisions. This not only implies a high spatial resolution but also very detailed information. National or regional map products are developed in many countries to also support the management level while European-wide products will not fulfil the necessary requirements. Such products should be explicit in stating that they cannot fulfil the needs for the management level. To provide an example, a tree species map for *Pinus nigra* for the same region in Austria is used, where the differences between the quality becomes obvious (Figures 3 and 4). Furthermore, the example for the vegetation height models clearly shows the differences in quality using a national approach (Figure 5) or a European one (Figure 6). The European approach does not include higher values than 25 m whereas in the national model, the maximum heights are above 40 m. The height variability is very low for the European product in comparison to the national product.

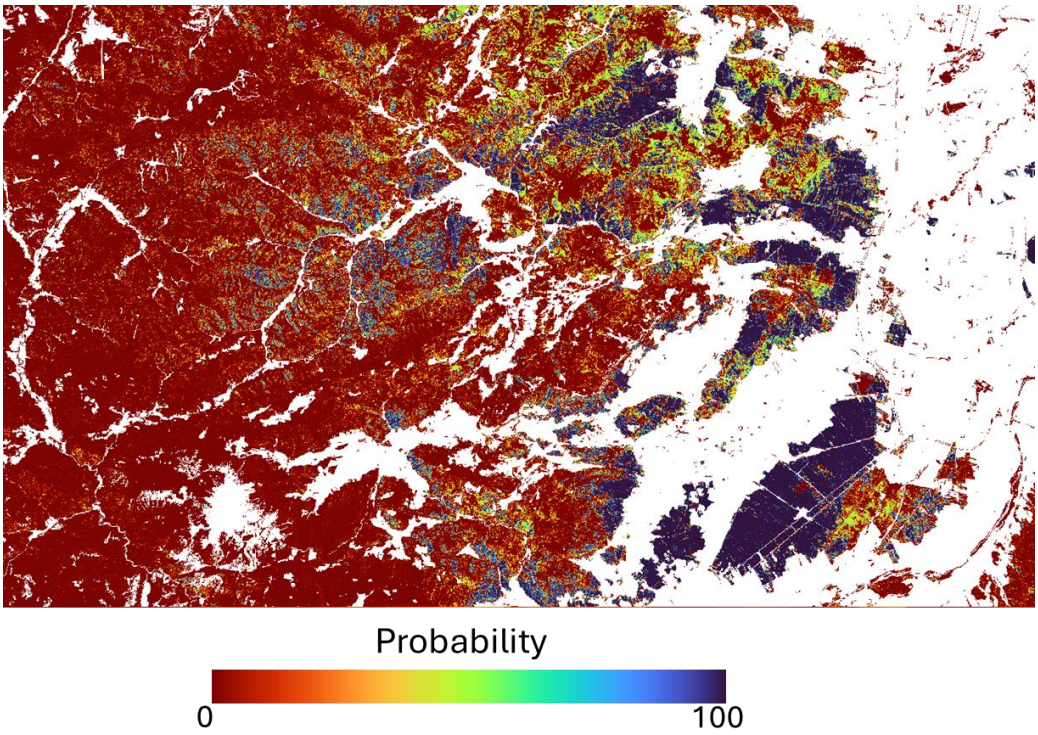

Figure 3: Map for Pinus nigra at the eastern alpine border developed by the Austrian NFI (For more information see Schadauer et al. (2024b)).

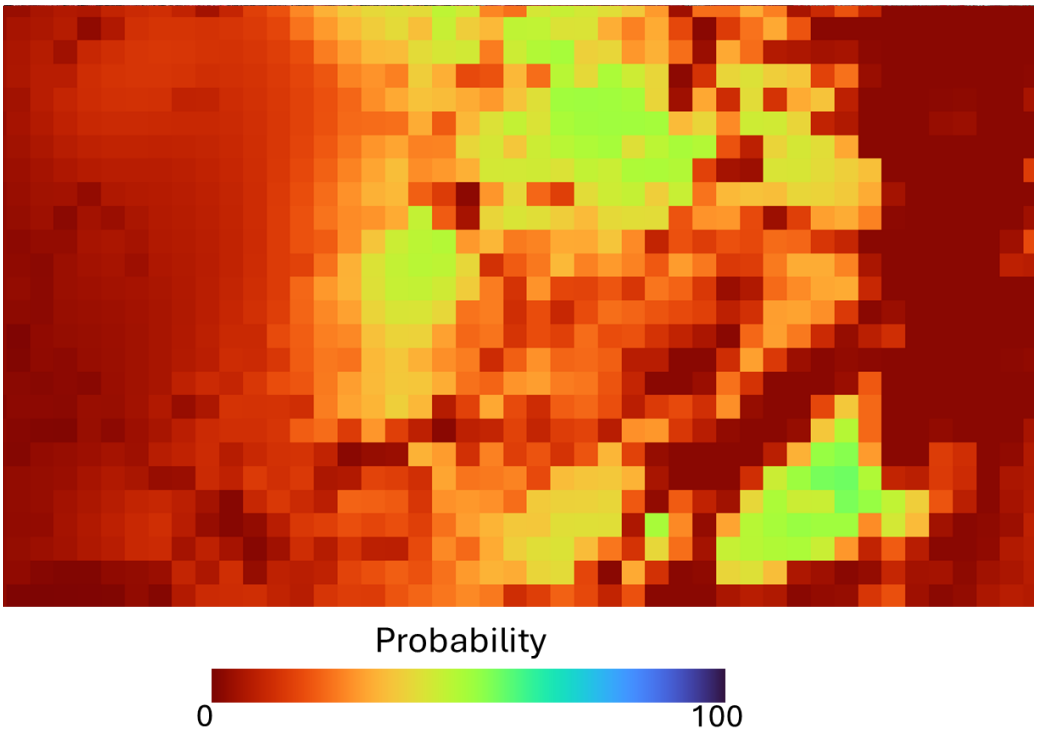

Figure 4: Map for Pinus nigra at the eastern alpine border developed by the JRC (Source: https://forest.jrc.ec.europa.eu/en/european-atlas/)

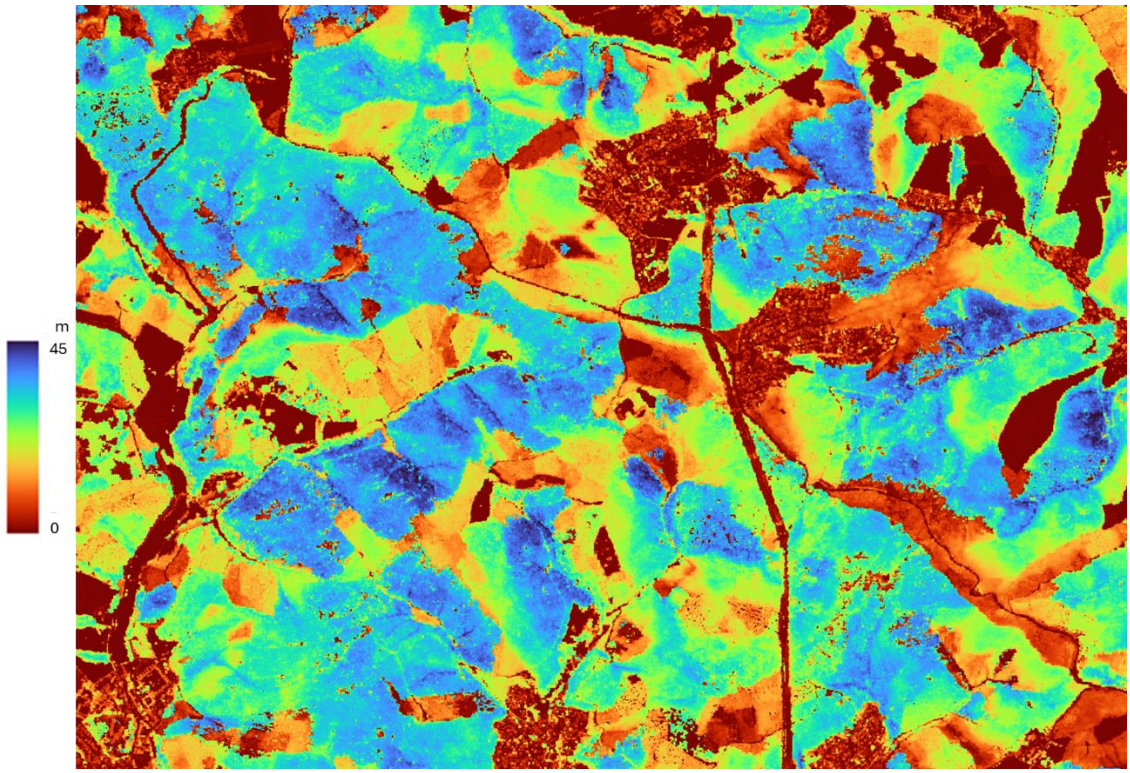

Figure 5:Vegetation height model at the east of Vienna developed by the Austrian NFI (Schadauer et al., 2024b)

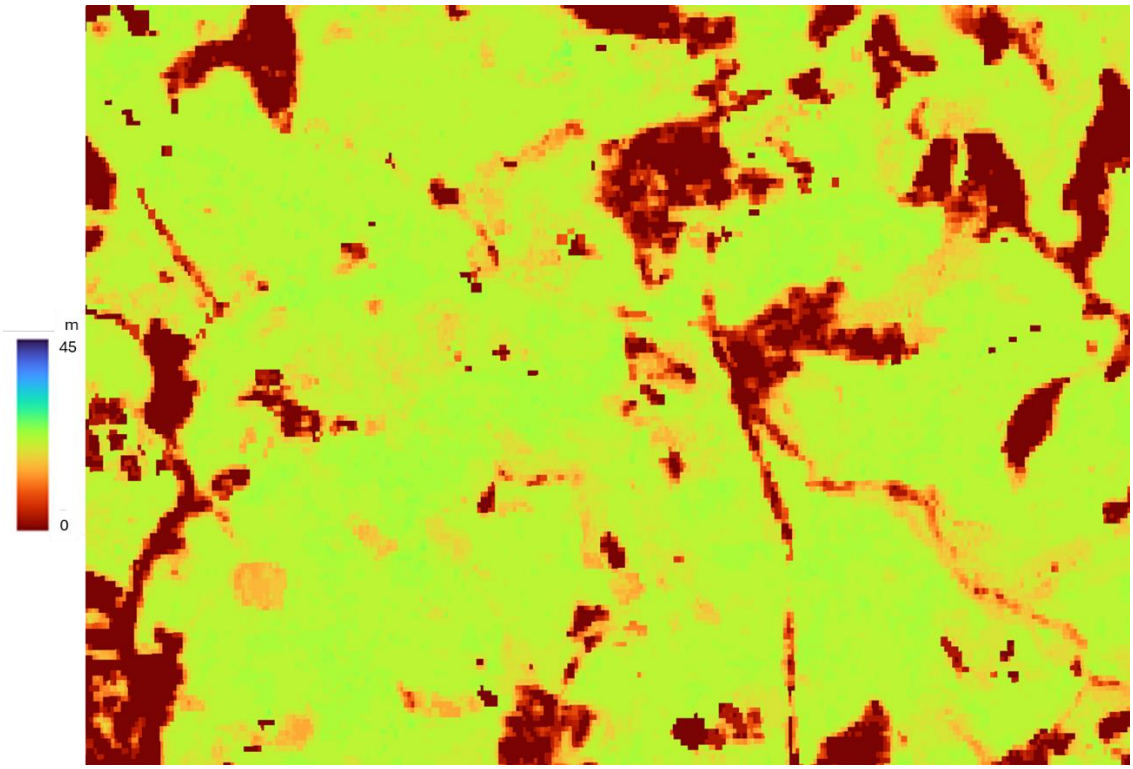

Figure 6: Vegetation height model at the east of Vienna (Source: https://glad.umd.edu/users/Potapov/Europe_TCH/Tree_Height/)

The European-wide product cannot be used for local management decisions. Even if the quality of the European products will evolve in upcoming years, the national data and model developments can

always include regional expertise and thus be more locally adapted leading to better qualities. It is the responsibility of the MS to develop such maps according to the subsidiarity principle. Nevertheless, an exchange of expertise and support for some countries to produce such maps is within the scope of ENFIN and could be supported by the Commission, not necessarily within the frame of the EFMR.

3.2.7 Pros and cons of a holistic versus a more restricted approach

The EFMR aims to improve forest monitoring across Europe by ambitiously promising a comprehensive scope covering multiple aspects of forest health and management. According to the European Commission's proposal, the framework aims to provide "open access to detailed, accurate and timely information on the status and trends of EU forests" (EC 2023). It encompasses various parameters, including climate change, biodiversity, forest health, and invasive species, demonstrating its broad coverage of forest-related issues.

Nevertheless, the EFMR faces significant challenges in terms of its broad scope, lack of specificity in methodologies, and potential implementation inconsistencies:

- The European Forest Institute (EFI) notes that the regulation attempts to address a **wide range of parameters and objectives** simultaneously, which may prove **difficult to implement** effectively across all Member States (Pecurul-Botines et al. 2023). Addressing these concerns will be crucial for the regulation's success in providing accurate and comparable data on European forests.
- Feretti et al. (2024) state that the EFMR **lacks the integration of some crucial and readily available resources and infrastructures** at the ICP-Forests. Especially assessments of biodiversity (e.g. ground vegetation) and soil including carbon are relevant for the EFMS.
- The European Parliamentary Research Service (EPRS) highlights that current forest monitoring data in the EU lacks consistency, detail, and standardised collection methods (EPRS 2024). This **lack of specificity in the proposed regulation** could perpetuate these issues, potentially undermining the goal of harmonised data collection across Member States.
- The unclear funding and resource allocation is a significant concern, as is the potential for inconsistent implementation across Member States. The EPRS impact assessment notes that the **proposal does not clearly outline the funding and resources required** for its implementation, potentially burdening Member States with additional costs (EPRS 2024).
- Furthermore, **variations in national capacities and existing monitoring systems may lead to uneven application of the regulation**, affecting data quality and comparability (European Parliament 2024).
- EUSTAFOR, representing State Forest Management Organizations across Europe, emphasises the need for the regulation to **"respect the Member States' competence and build upon the principles of subsidiarity and proportionality"** (EUSTAFOR 2024). There is the potential for political resistance to centralised monitoring.

3.3 Defining the goals for EFM

Given the discussion above, the main goal of EFM is to support European forest related policies by:

- Providing information on status and changes of the main forest attributes linked to climate change, forest resources and forest management considering the multifunctionality of forest ecosystems and including a defined level of accuracy linked to the temporal resolution.
- Monitoring for the purpose of research to investigate the improved resilience of forest ecosystems.

- The main beneficiary of the EFMS is the European Commission: The primary source to support national forest policy is based on national monitoring systems.

Consequently, the following are critical issues of EFM:

- Support of local forest management: This kind of support needs a very detailed local expertise and data which can be handled best at national, regional and local scales.
- Duplication of legally binding assessments that are already handled in other EU regulations. A duplication would lead to unnecessary inconsistencies and a loss of clarity.
- Use existing remotely sensed EU-wide products and include them as inadequate proxies in the system. To produce such maps no EU regulation is necessary.

3.4 A Potential Governance Structure for a European Forest Monitoring System

A possible approach to forest monitoring at the EU level could be a step-wise development. Such an approach will allow for iterative improvement and adaptation. It will also allow for the development of protocols for forest inventory and monitoring across all Member States. This includes standardised definitions, measurement techniques, and data collection procedures to ensure consistency and comparability. The setup of such a framework requires a clear funding mechanism that outlines the financial and resource allocation for the framework. This should include contributions from the EU budget and Member States, ensuring long-term, stable funding.

The U.S. Forest Inventory and Analysis (FIA) program could provide valuable examples for developing a forest monitoring framework (Bechtold and Patterson 2005). The FIA was developed gradually, starting with core inventory protocols and expanding to include additional monitoring objectives (Hoover et al. 2022). It established standardised methodologies for data collection and analysis, ensuring data comparability across states. The FIA successfully integrated remote sensing technologies with ground-based data collection and involved stakeholders at all levels, from local communities to federal agencies, ensuring broad support and participation.

A potential governance structure for a European Forest Monitoring System would employ a bottom-up approach, leveraging existing national-level data collection efforts while harmonising and standardising information at the European level as requested in the EFMR (European Commission, 2023). This structure recognises the diverse forest ecosystems and management practices across Member States while enabling a comprehensive and consistent view of European forests.

The governance structure for the European forest monitoring system includes several key components and stakeholders, each with specific roles and responsibilities (See Figure 7).

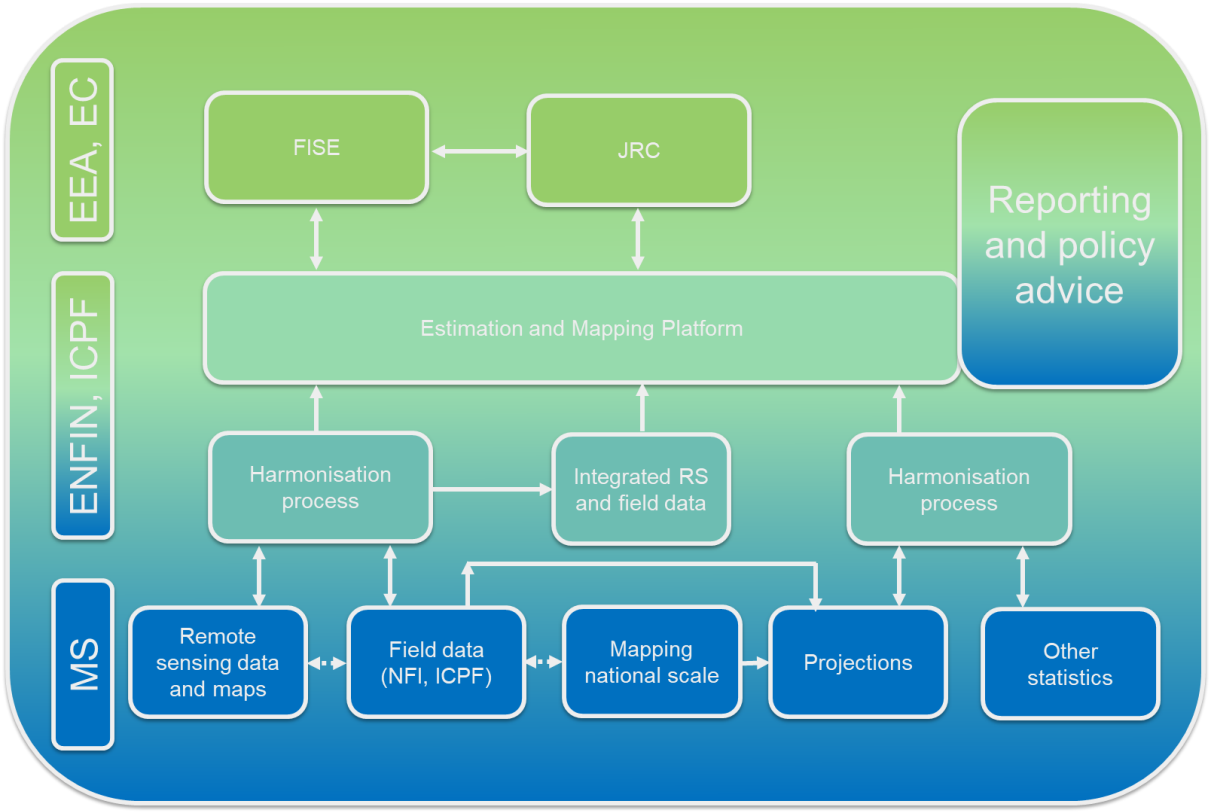

Figure 7: Proposed governance structure of the EFMS

The Member States play a crucial role in collecting and sharing harmonised forest data. They utilise their existing National Forest Inventories (NFIs), ICP Forests plots, and other monitoring networks to gather field data. This approach respects the principle of subsidiarity and capitalises on the extensive expertise and established methodologies at the national level (Ferretti, 2021). Member States are also responsible for integrating field observations with remote sensing data and other relevant statistics to provide a more comprehensive picture of their forests. The bottom-up structure is further reinforced by the designation of national correspondents, who serve as liaisons between Member States and the European level and are closely linked to ENFIN. These correspondents coordinate data preparation, ensure compliance with technical specifications, and facilitate communication between national authorities and the Commission.

ENFIN and ICP Forests play a vital role as expert groups in supporting the Commission by developing common descriptions and protocols, facilitating coordination, and exchanging good practices among Member States. They help to bridge the gap between national and European-level monitoring efforts and ensure that the system remains scientifically sound and practically applicable (Ferretti, 2021). The above-described approach has been adopted and proven effective by the ICP Forests (see Figure 1).

In the following paragraphs, some aspects of the structure are described in more detail:

- Decisions on the data need are relevant to reach the goal

To be able to meet the goals of European Forest Monitoring a clear structure for the decisions in which data have to be assessed is needed. This includes data from sampling in the forests as well as data from remote sensing. It starts with the work of monitoring expert groups (ENFIN and ICP

Forests) based on their long-time experience. They propose the list of data needed. In the second step, this set of data will be evaluated also by the expert group concerning their efficiency and a rough estimation of costs. With this output the European Commission and Member States (i.e. expert group) should discuss and finally decide on the proposed list.

- Decisions on the technical specifications

For each of the variables to be assessed, technical specifications have to be elaborated. This should be done in the same expert group which proposed the list of variables. In this first step, this forum proposes the specifications. They will be sent out to all European NFIs and Members of ICP Forests in order to be discussed and checked by all Member States. Finally, they will be discussed with the Commission.

- Data acquisition including RS

Sample-based data: The data acquisition/collection will be executed by the NFIs and by member organisations of the ICP Forests within their ordinary assessments. The assessment rules are part of the report for data delivery. The few European countries, which do not yet have an established NFI or ICP Forests system, receive support to establish a system and start with the assessments in a later phase of the European Forest Monitoring system.

Remotely sensed data: Depending on if they are space-borne or airborne data they are acquired at the national level or at the European level. E.g. for the Sentinel data, the assessment is rather straight forward, they can be downloaded from several servers. For the airborne data the circumstances are different in different Member States. As the data at Member State level have different ownerships and licencing for the use for forest monitoring, a description of the rights of use is part of the data delivery. If modelling approaches are needed, for example to map old growth forests, the methods are described in detail.

- Data storage

Sample-based data: The data are stored in national systems. First, checks for completeness and for consistency are executed and the preprocessing including harmonisation of data is executed at the Member State level. A generic database structure capable of statistical estimations crossing different statistical designs is developed within PathFinder (nFiesta) and the data are uploaded to this system by the Member States.

Remotely sensed data: For the RS data a system is established to link the data to the plot coordinates within the Member States, without making the coordinates as such available. A system ensuring the coordinates remain secret is essential, including the interdiction of re-engineering plot coordinates.

The nFiesta (new Forest Inventory ESTimation and Analysis) software plays a pivotal role in this governance structure by enabling the integration and analysis of NFI data with auxiliary data sources (Figure). Developed as part of the Horizon 2020 DIABOLO project, nFiesta is designed to integrate and harmonise NFI data across Europe, providing a robust framework for statistical estimation and analysis of forest attributes (Adolt et al., 2018).

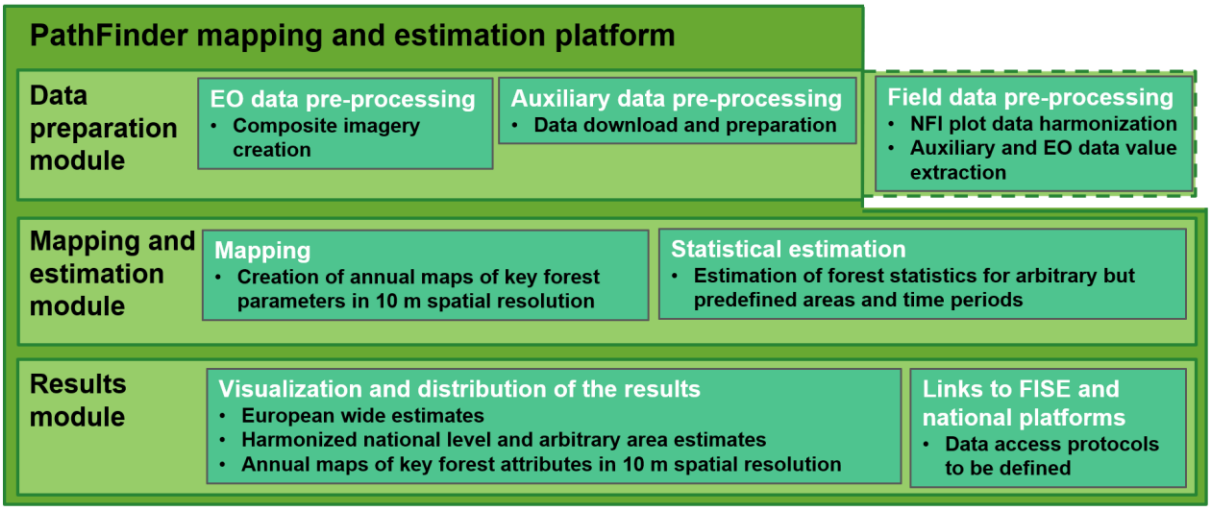

Figure8: The PathFinder mapping and estimation module which incorporates nFiesta as a module (modified from Miettinen et al. 2024)

The bottom-up approach makes sense in this context for several reasons (Mann et al. 2022). Firstly, it respects the diversity of forest ecosystems and management practices across Europe while still achieving harmonisation. Secondly, it builds upon existing national expertise and infrastructure, reducing duplication of efforts and ensuring cost-effectiveness. Lastly, it promotes a sense of ownership and engagement among Member States, potentially leading to higher-quality data and more effective implementation of the monitoring system.

This part of the governance structure aligns with the objectives outlined in the EU Forest Strategy for 2030, which emphasises the need for improved and harmonised EU-level forest monitoring and data collection (European Commission, 2021). It also addresses the challenges identified in recent studies, such as the fragmentation and inconsistency of information concerning the status of forests in the EU, their social and economic value, and the pressures they face.

Such a governance structure would present a collaborative effort involving the European Commission, Member States, the EEA, and other stakeholders. Each plays a critical role in ensuring the collection, analysis, and dissemination of high-quality forest data. The nFiesta software is integral to this structure, supporting the bottom-up approach and enabling the harmonisation of data across the EU. This coordinated effort ensures that the monitoring system can effectively support evidence-based policymaking and contribute to the resilience and sustainability of European forests.

3.4.1 Data privacy solutions

Potential solutions regarding data privacy could be to develop a tiered data-sharing system where only aggregated or generalised data is made fully public, but where more detailed data, including approximate plot locations, is shared between authorities under strict confidentiality agreements, and precise plot coordinates are kept confidential by Member States but can be used to contribute to EU-wide analyses when necessary. Implementing robust technical and legal safeguards for handling sensitive geospatial data involves data anonymisation techniques, restricted access protocols, and legal frameworks to protect data providers.

Another option could be to allow Member States flexibility in how they contribute data, such as options to provide data at different levels of spatial precision, aggregate data to larger geographic units, and use data masking or perturbation techniques to protect exact locations while maintaining

statistical validity. In any case, it is crucial to develop clear guidelines and standards for data sensitivity classification and handling procedures across Member States.

The discussion above is closely linked to the discussion on what data type, and resolution (spatial and temporal) is needed for monitoring forests at the European level, which in the end is the aim of the EFMR. Addressing these privacy and sensitivity concerns explicitly is key to ensuring Member State cooperation while still achieving its goals of improved, harmonised forest monitoring across the EU.

3.4.2 Proposed governance to increase the interactions with the key actors

The interaction with key actors will be facilitated through the governance framework, which includes national correspondents and expert groups to ensure comprehensive and coordinated data collection and reporting (EC 2023a, 2023b).

One important process regards the proposal to amend Council Decision 89/367/EEC, which originally established the Standing Forestry Committee, was presented by the European Commission on 22 November 2023 (10896/24, 16064/24, COM(2023) 727 final). The proposed amendments were intended to align with the EU Forest Strategy for 2030 by ensuring that the governance structure could effectively address the increasing societal demands on forests, balancing social, economic, biodiversity, and climate-related aspects. The strategy emphasises the need for a multidisciplinary exchange and cooperation between Member States and the Commission to achieve the objectives of the European Green Deal and other related policies.

The Commission presented the proposal to the Working Party on Forestry on 5 December 2023 and to the Agriculture and Fisheries Council on 11 December 2023. A first proposal was to rename the Standing Forestry Committee to the "Standing Forest and Forestry Expert Group" to better reflect its updated role and composition. The amended objectives would be to create a more inclusive and better-coordinated EU forest governance structure that reflects the multifunctional role of forests and their contributions to the European Green Deal objectives (10896/24, 16064/24). The membership would be extended to include authorities competent for various policy objectives such as climate, forest health, environment, forestry, rural development, and bioeconomy. The tasks of the committee would be broadened to assist in the preparation and implementation of relevant legislative proposals, strategies, and guidelines. Several meetings, in total five, were held from December 2023 to June 2024 involving the WP on Forestry, The Agriculture and Fisheries Council and MS delegations, until the endorsement of a permanent Representatives Committee of the latest composed text.

The proposal was ultimately withdrawn due to concerns raised by the Commission regarding the name, composition, and tasks of the expert group, as well as the requirement for the Commission to provide feedback to the expert group and changes in the legal format. This withdrawal affects governance by maintaining the status quo of the Standing Forestry Committee, potentially delaying the implementation of a more inclusive and coordinated governance structure as envisioned in the New EU Forest Strategy for 2030.

3.4.3 Responsibilities for MS, Commission and EEA

At the core of this governance structure is the European Commission, which is responsible for the overall coordination of the monitoring system. The Commission designs the intervention logic, explains the reporting obligations to Member States, and assists them in preparing their reports. It also organises the data submission or harvesting process, ensures the quality of the reported data, carries out data processing and analysis, and presents and disseminates the results. Ultimately, the

Commission publishes the official reports, ensuring that the data is accessible and useful for policymaking and public information.

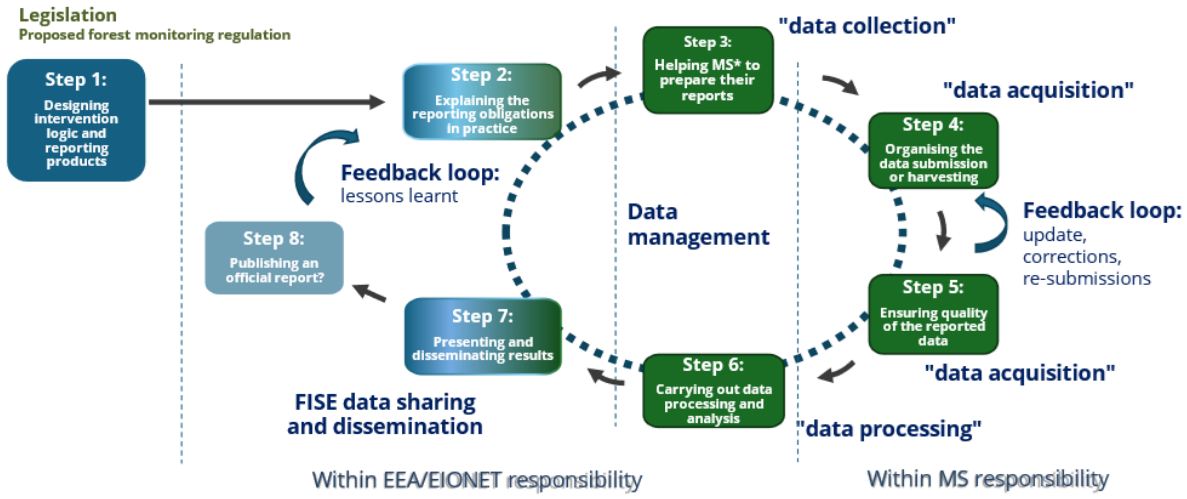

*Figure 9: Steps for the flow of data and work packages towards European forest information (modified from TRASYS International 2018). * MS means relevant national authority responsible for environmental reporting*

Member States, through their relevant national authorities responsible for forest reporting, play a crucial role in this structure. They are tasked with preparing reports or making required data available. Member States are also responsible for responding to feedback from the Commission and making any necessary corrections or re-submissions to ensure data accuracy and completeness.

ENFIN and ICP Forests play a vital role in supporting the steps “explain the reporting obligations” (Figure 9, Step 2) to finally “presenting and disseminating the results” (Figure 9, Step 7) and “Publishing an official report” (Figure 9, Step 8).

The European Environment Agency (EEA) and the European Environment Information and Observation Network (EIONET) support the Commission by managing data collection, acquisition, and processing. They are also responsible for the Forest Information System for Europe (FISE), which facilitates data sharing and dissemination. The EEA's role includes providing technical expertise and ensuring that the data collected is of high quality and meets the required standards.

Quality assurance and quality control (QA/QC) are integral parts of the governance structure, occurring at multiple stages of the data flow. QA/QC processes are implemented within Member States before data submission, during the submission or harvesting process by the Commission, and during data processing and analysis by the Commission. These measures ensure the integrity and reliability of the data throughout the monitoring process.

Feedback loops are an essential component of the governance structure, allowing for continuous improvement and adaptation. Updates, corrections, and re-submissions flow from the Commission back to Member States, ensuring that any issues are promptly addressed. Additionally, lessons learned from each reporting cycle inform future improvements to the system, enhancing its effectiveness and efficiency over time.

3.5 Estimation of costs

Estimation of costs of a European Forest Monitoring Framework is challenging. This Subsection outlines the possible costs, assuming the list of indicators of Annexes I and II of the EFMR. The EFMR attempts to minimise the additional costs of establishing an EFMS by largely relying on already

existing indicators for which data to some, but not sufficient, extent already exist. This applies for most of the EFMR Annex I and Annex II indicators, but not for the Annex III indicators.

In the following Member State level examples, we estimate the costs introduced by the data flow Steps 3 - 6 in Figure 9. The costs include additional data collection, data processing and harmonisation efforts in selected Member States, but not any of the fixed costs of the already existing NFIs. Thus, the examples are based on the assumption that the selected Member States will continue their NFI due to national-level information needs. The Additional harmonisation budget line includes participation in the expert meetings and the actual harmonisation work with the national data.

3.5.1 Example Austria:

Costs Annex I (opt-out variant):

Table 4: Costs for Austria if Annex I of the current EFMR was adopted and the opt-out option was chosen.

Position	**Euro once**	**Euro/year**
Additional software development	200,000	
Additional data handling and software updates		150,000
Additional Hardware	30,000	
Total	**230,000**	**150,000**

Costs Annex II

Table 5: Costs for Austria for "NFI" Indicators (a to h) of Annex II of the current EFMR if it was adopted in its current form - depending on the forest definition: national (ND) or other definition (OD) and the level of EU wide harmonisation.

Position (ND)	**Euro once**	**Euro/year**
Additional harmonisation	150,000	
Additional software development	50,000	
Additional data preparation (per 5 Years)	20,000	
Total (ND)	**220,000**	
Position (OD)		
Additional filed assessments		200,000
Additional cost for duplication of the database		10,000
Total (OD)		**210,000**

Other indicators:

*Table 6: Costs for Austria for indicators i, j, k, l, m and n of Annex II of the current EFMR if it was adopted in its current form. *It is not possible to estimate the area of Old-growth forests yet.*

Position	**Euro once**	**Euro/year**
Location of Forest Habitats in Natura 2000 sites	30,000,000	
Abundance of common forest birds (citizen science)	300,000	
Location of primary and old-growth forests	2,500,000	Contracts with landowners 250€/ha
Protected forest areas	30,000	
Production and trade of wood products & forest biomass for bioenergy	10,000	

Total	**32,840,000**	**Contracts with landowners 250€/ha***

The reimbursement of landowners for not using in forests declared as primary and old-growth forests will cause the highest costs by far.

Annex III:
Cannot be calculated because it is unclear which kind of financing system is considered. However, the location of forest habitats outside Natura 2000 sites is much more expensive than Annex II.

3.5.2 Example Finland:

Costs Annex II

Table 7: Costs for "NFI" Indicators (a to h) of Annex II of the current EFMR if it was adopted in its current form - depending on the forest definition: national (ND) or other definition (OD) and the level of EU wide harmonisation.

Position (ND)	**Euro once**	**Euro/year**
Additional harmonisation	150,000	
Additional software development	50,000	
Additional data preparation (per 5 Years)	20,000	
Total (ND)	**220,000**	
Position (OD)		
Additional field assessments		300,000
Additional cost for duplication of the database		10,000
Total (OD)	**220,000**	**310,000**

Other indicators:

*Table 8: Costs for Finland for indicators i, j, k, l, m, and n of Annex II of the current EFMR if it was adopted in its current form. *Prioritised action framework for Natura 2000 in Finland including the Province of Åland for the Multiannual Financial Framework period 2021-2027. Ministry of Environment 2021.*

Position	**Euro once**	**Euro/year**
Location of Forest Habitats in Natura 2000 sites	1,400,000*	290,000
Abundance of common forest birds (citizen science)	300,000	
Location of primary and old-growth forests	10,000,000 – 15,000,000	
Protected forest areas	0	
Production and trade of wood products & forest biomass for bioenergy	10,000	
Total	**11,710,000 – 16,710,000**	**290,000**

Annex III:
Cannot be calculated because it is unclear which kind of financing system is considered. Mapping the location of forest habitats outside Natura 2000 sites is very expensive, even more expensive than the mapping of old-growth and primary forests.

3.5.3 Example Germany:

Costs Annex I (opt-out variant):

Table 9: Costs for Germany if Annex I of the current EFMR was adopted and the opt-out option was chosen.

Position	Euro once	Euro/year
Additional permanent employees for methodology development		500,000
Additional employees with limited contracts (3 years) for support and collection of reference and validation data		200,000
Additional computing capacity and collecting reference data		500,000
Total		**1,200,000**

Possibly higher costs through not yet published implemented acts that might change methodology and/or requirements concerning the accuracy.

Costs Annex II

Table 10: Costs for Germany for "NFI" Indicators (a to h) of Annex II of the current EFMR if it was adopted in its current form - clustered by costs for additional processing and harmonisation and the change of the inventory cycle.

Position	Euro once	Euro/year
Changing the NFI cycle from 10 to 5 years (per 5 years)	28,000,000	500,000
Additional harmonisation and processing of new indicators		100,000
Additional quality control, archiving and distribution to EU (per 5 Years)	65,000	
Total	**28,065,000**	**600,000**

Costs for the indicators i, j, k, and l could potentially be handled by combining existing Map data. It remains unclear how much field assessments would be necessary.

3.5.4 Findings from the examples AT, FI and DE:

In general, it is difficult to estimate the costs, because the information provided by the EFMR is not explicit enough. Austria and Germany provided estimated Costs for Annex I, that might arise from choosing to opt out, ranging from 0.15 to 1.2 m €/year. For Annex II all three countries estimated the costs for the indicators from a to h ranging from 0.2 to 0.3 m €/year for Austria and Finland. For Germany very hight costs of around 28 million €/year would arise from changing their NFI cycle from ten to five years. Costs for indicators i, j, k, l, m and n of Annex II were estimated by Finland an Austria ranging from roughly 11 to 33 million €. The yearly reimbursement of landowners for restricted use on land classified as primary or old-growth forest was only mentioned by Austria. However, with yearly payments of 250€/ha they will exceed the other estimated costs drastically. For Annex III neither of the three countries could provide cost estimates as there are too many uncertainties in the current version of the proposal, leading to highly inaccurate estimates. The impact assessment regarding the EFMR provided by the European Commission (EC 2023c) does not

estimate the costs for the indicators collected in Annex I – III. Yet, reliable estimates of how much the implementation of an EFMS costs for Member States is needed before it is proposed.

4. Conclusion and advice

The EFMR presents a significant opportunity to enhance our understanding of European forests. It seeks to integrate remote sensing data with NFI data to improve forest data on multiple scales. Challenges include implementing advanced technologies, ensuring data integrity, and managing costs. Despite these challenges, the EFMR promises significant benefits for several stakeholders, including EU forest-related policies. Robust, integrated data collection and reporting mechanisms are crucial for the regulation's success, enhancing forest monitoring and supporting comprehensive LULUCF reporting and climate targets. When deciding on the implementation through legally binding or non-binding mechanisms, possible infringement on national sovereignty and the effectiveness of the mechanism should be carefully evaluated. Several key aspects need to be considered for the successful implementation of an EFM system:

- Define the goals in more detail to be able to develop the system
  The EFMR defines the goals very broadly. In order to set up a monitoring system for Europe, more concrete goals for the monitoring are essential instead of a general list of forest-related policies which the monitoring should serve.
- Focus on forest monitoring
  It is crucial that existing related policies are not changed in their content, due to a monitoring regulation. In other words, focus on setting up a Framework for a EFMS instead of directly defining implementation rules of other political agendas. One example is the legally binding mapping of old-growth forest, which can be of interest, but is out of scope of setting the legal basis of a EFMS.
- Quality Management – use statistical estimates, no quality “down-levelling” for standardised European approaches
  Quality management is an essential feature of evidence-based policy. Therefore, enough room for QA/QC has to be given in all parts of the system. Use statistical, sample-based estimation as far as possible. In the rare situations where timeliness is really important at the European scale, the information derived from remote sensed and model-based predictions have to be rigorously evaluated, before they are used for decision making. The approach of developing a standardised European Map with low or unknown quality in relation to the national products does not fulfil this quality requirement.
- Step-wise and Bottom Up – full use of expertise within NFIs, ENFIN and ICP structures as well as PathFinder findings
  The expertise for forest monitoring has been developed within the Member States for up to 105 years. For the Commission this field is new. Therefore, a stepwise and strong bottom-up approach is needed to make best use of monitoring expert knowledge. Such an approach will allow for iterative improvement and adaptation. It will also allow for the development of protocols for forest inventory and monitoring across all Member States. Furthermore, for the validation of RS products a bottom-up approach is essential.
- Focus on forest information instead of on plot data
  Monitoring systems are developed to derive relevant information. This information should always be produced by experts. Forest statistic experts derive this information. The EC as user of the Information does not need plot data, except for cases where the data are used

for research. A meaningful reporting unit needs to be defined. In the EFMR context, we recommend a thorough analysis on how to define the "Forest Management Unit".

- Avoid inadequate proxies derived from remote sensing
  One example for this is the assessment of Leaf Area Index (LAI) via remote sensing as a proxy for defoliation or forest health. Such an assessment cannot be justified as there is not a close correlation between the LAI and defoliation or forest health and the spatial resolution of 300 m² seems arbitrary.
- Data privacy and sensitivity concerns must be addressed explicitly to ensure MS cooperation. Potential solutions include developing a tiered data-sharing system, implementing robust technical and legal safeguards, and allowing flexibility in how member states contribute data.
- Include realistic estimations of Costs
  The impact assessment of the Commission (EC 2023c) does not reflect realistic costs to serve all indicators in the three annexes. Costs are by far underestimated, relying too much on simple and cheap remote sensing solutions.
- Support for some Member States in terms of expertise and funds to ensure high-quality standards in every Member State
  Member States have different importance of the forest and environmental sectors leading to differences in the forest monitoring systems. Countries that have not yet set up high-quality systems should be supported with expertise from other countries and with funds.
- Promote increased interaction between key actors
  The governance structure should facilitate increased interaction with key actors, including national correspondents and expert groups. The proposed amendments to the Standing Forestry Committee, while currently withdrawn, highlight the need for a more inclusive and coordinated governance structure that reflects the multifunctional role of forests

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