TRANSFORMIT

Deliverable 5.2

Participatory agreed set of key indicators for monitoring and reporting IFM

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Executive Summary

Integrative Forest Management (IFM), as defined in WP3 of the TRANSFORMIT project, "aims at integrating biodiversity conservation and global change adaptation into forest management for the sustainable provision of multiple ecosystem services. It is guided by natural and diverse forest structures, compositions, and dynamics to support ecosystem functioning and resilience. Its management practices consistently consider the tree, stand, and landscape scale and employ different silvicultural intensities, including intentionally unmanaged forests. IFM can be applied in any type of forest to achieve integrated environmental, economic, and social outcomes." To measure progress towards IFM effectively, a participatory process was undertaken to develop a set of key indicators. Indicators are measurable variables or metrics that provide insights into the progress or effectiveness of specific goals or targets. When carefully selected to ensure they are relevant, sensitive to IFM, feasible, and aligned with policy goals, indicators become effective tools for monitoring and decision-making.

We started in Task 5.2 with a pool of about 80 indicators identified in Task 5.1 from international frameworks, projects and certification schemes as potentially relevant to monitor IFM (see Deliverable 5.1). Through a series of iterative workshops and stakeholder engagement, this pool of indicators was refined to a final set of 17 key indicators for IFM relevant across all Living Labs involved in the project and aligned with international and EU strategies, directives and guidelines. Detailed factsheets were created for each indicator, covering rationales, characteristics, trade-offs, regional differences, local- and national-level measurement units, data sources, targets and thresholds.

The indicators are designed to be scalable from local to national/European levels, focusing on aspects of provision of forest ecosystem services, biodiversity conservation, enhancement of forest resilience and climate change adaptation. The participatory process ensured alignment with practical realities, fostering local ownership and increasing the likelihood of successful implementation in monitoring IFM and providing decision support.

Innovative elements of the indicator system include a holistic and scalable framework, stakeholder-driven development, and target-related assessment linked to policy goals. These indicators provide a robust framework for monitoring, reporting, and decision-making, ensuring that IFM principles are effectively implemented across diverse forest types and scales. By combining various indicator selection approaches, stakeholder engagement, alignment to EU forest and biodiversity policy, the resulting key indicators contribute to global and European biodiversity and climate goals while addressing local needs and realities.

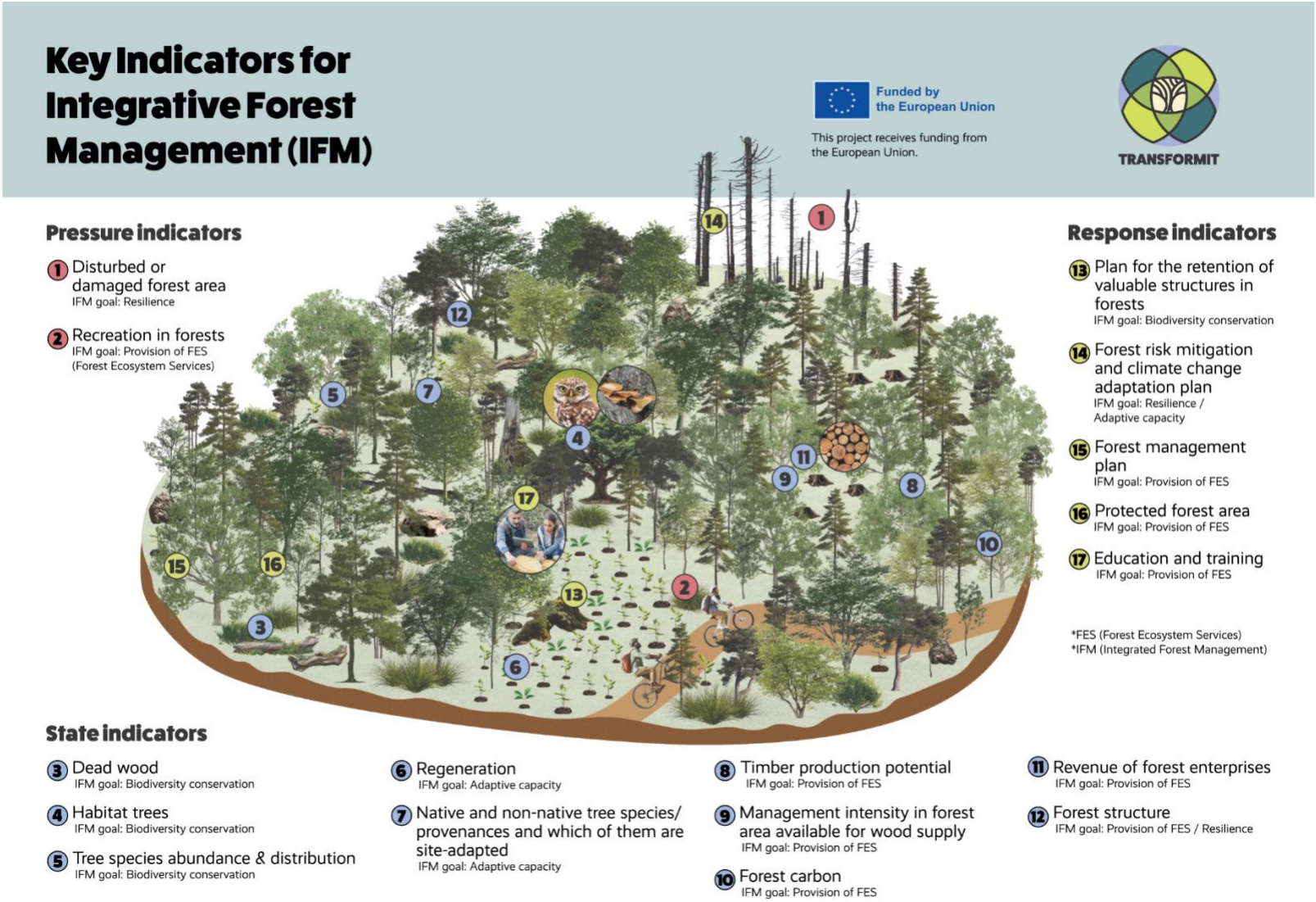
Deliverable 5.2 contributes to the overall objective of TRANSFORMIT by providing a robust and operational framework for monitoring and reporting IFM, which is essential for demonstrating and verifying the effectiveness of IFM measures in achieving EU forest policy targets as part of the EU Green Deal, Biodiversity Strategy, and the EU Forest Strategy 2030. The indicators developed in this Deliverable are directly linked to the project's goal of integrating biodiversity conservation and sustainable forest management, supporting the diversification of IFM methods, and addressing context-dependent forest management approaches. The indicators are also the basis for Deliverable 5.3, which facilitates evidence-based monitoring of the key IFM indicator variables. Furthermore, the indicators are designed to be integrated into Decision Support Tools (DSTs) and forest modelling, which are key outputs of TRANSFORMIT Task 5.4, Task 6.1, and Task 6.3. This ensures that the indicators not only serve as monitoring tools but also actively contribute to decision-making processes and the development of innovative technologies, such as interactive digital twins of forests. Additionally, the participatory process used to develop the indicators aligns with the project's

emphasis on stakeholder engagement and mutual learning, as outlined in the Stakeholder Engagement Platform of WP2 and the interaction with the Living Labs in WP4.

Keywords

TRANSFORMIT, integrative forest management, indicators, key indicators for IFM, decision support, policy alignment, monitoring, data, targets, participatory process

Graphical abstract / Infographic



1. Introduction and objectives

Integrative Forest Management (IFM), as defined in WP3 of the TRANSFORMIT project, aims to integrate biodiversity conservation and global change adaptation into forest management practices to ensure the sustainable provision of multiple ecosystem services. IFM is guided by natural and diverse forest structures, compositions, and dynamics to support ecosystem functioning and resilience.

Its management practices consistently consider multiple spatial scales and employ a range of silvicultural intensities, including intentionally unmanaged forests. IFM can be applied in any type of forest to achieve integrated environmental, economic, and social outcomes.

The overarching goals of IFM include:

i) Biodiversity conservation,

ii) Provision of forest ecosystem services,

iii) Enhancement of forest resilience, and

iv) Adaptive capacity to climate change.

To measure and assess IFM effectively, Task 5.2 focused on developing a set of key indicators.

Over the past 30 years criteria and indicators (C&I) have emerged as powerful tools with significant potential for facilitating decision-making in and about forest management. Forest-related C&I can be applied at global, regional, international, national, subnational, and forest management unit levels. However, only very specific sets are scalable across these various levels. C&I can also be customised to allow for differences within and between countries, regions, and specific locations (Linser et al., 2018; Linser & Wolfslehner, 2022).

Criteria outline what is important to measure, while indicators specify how to measure it (Linser & O'Hara, 2019). In this work, criteria correspond to the goals of IFM, defining the essential elements against which IFM is assessed. Indicators reduce large amounts of data into a simpler form, making complex circumstances feasibly measurable and comprehensible to decision-makers and the public (Linser, 1999, 2002; McCool & Stankey, 2001; Shields, 2002; Wolfslehner et al., 2016). In short, the purpose of an indicator or a set of key indicators is to facilitate simplification (Ott, 1978).

Task 5.1 *(Pool of potentially relevant indicators for IFM)*, conducted during the first six months of the TRANSFORMIT project, involved screening and reviewing existing forest-related indicator sets from sources such as the Convention on Biological Diversity (CBD), Forest Europe, the Montréal Process, the United Nations Sustainable Development Goals (UN SDGs), and certification schemes like FSC and PEFC. This process, supplemented by literature reviews, resulted in a pool of approximately 80 potentially relevant indicators for IFM (see Deliverable 5.1, June 2024).

The subsequent Task 5.2 *(Selection of key indicators for IFM)* aimed to condense this pool of indicators into a set of around 15 to 20 indicators that are relevant across all Living Labs (LLs) involved in the TRANSFORMIT project while considering scalability and feasibility for local and national-level assessments. These indicators are also intended to guide the selection of Decision Support Tools (DSTs) being applied and adapted in WP6 to support IFM in the Living Labs (see Milestone 6.1 report).

To ensure inclusivity and ownership, the selection and validation process involved forest managers, stakeholders, and research institutions through a series of workshops and consultations. This bottom-up approach fostered stronger engagement and involvement of local actors and stakeholders, making them feel ownership in the indicator selection process as it aligned with local needs and realities.

2. Indicator Workshops

2.1 First Indicator Workshop

The first indicator workshop (Milestone 13) was held online on 24 September 2024 and involved 16 participants from the consortium (a detailed participants list is in Milestone 13). These participants represented a diverse range of European research institutions and brought with them a variety of backgrounds, areas of expertise, and levels of seniority. Their experience with indicators ranged from hands-on, practical applications to more theoretical and conceptual approaches. This diversity ensured a comprehensive and balanced perspective in the discussion, as participants contributed already to the collation of the initial pool of indicators (see Deliverable 5.1 and information in the introduction above).

The objective of the workshop was to collaboratively review and reduce the number of potential IFM indicators, ensuring that they comply with the following criteria (Linser, 2002):

- Effectiveness (the ability of the indicator to accurately measure progress toward integrative forest management goals and provide actionable insights for decision-making),
- Relevance across the Living Labs (applicable and meaningful in boreal, temperate, and Mediterranean forest ecosystems),
- Scalability (suitable for application at multiple levels, from local to national scales),
- Feasibility (practical to implement with reasonable human and financial resources), and
- Comprehensibility (clear and easily understandable for forest managers and decision-makers).

As a basis for the workshop discussion, the 81 indicators were categorized under the following eight IFM principles[1] (defined in WP3), with two additional categories for socio-economic indicators (see also Figure 1):

1) Retention of habitat trees, special habitats, and dead wood
2) Promoting site-adapted native tree species and non-native species
3) Promoting natural tree regeneration
4) Partial harvest and promotion of structural heterogeneity
5) Promoting tree species variation and genetic diversity
6) Avoidance of intensive management operations
7) Supporting landscape heterogeneity and functioning
8) Management of factors that hinder ecosystem functioning

[1] https://transformforests.eu/wp-content/uploads/2024/05/Flyer_Call-for-IFM-enterprises.pdf

Using Zoom's polling feature and group discussions, all participants together evaluated the importance of each indicator based on the above-mentioned criteria. In this collaborative process, indicators were merged, renamed, or excluded based on their rankings of relevance in the context of the specific IFM principle and their general importance for IFM assessment. This process resulted in a reduced pool of 42 indicators.

Additionally, insights were gathered during the Integrate Network meeting (23–25 October 2024), where the approach to developing IFM indicators was discussed with small to large scale private and public forest owners practicing IFM. We spoke individually with each attending forest owner, explaining what indicators for IFM are and emphasizing our particular interest in whether they have strategies such as a deadwood retention strategy, a climate change adaptation strategy, or a risk mitigation strategy. We were particularly interested in this as the information is relevant for the selection of descriptive Response Indicators (for more information on the Pressure-State-Response Indicator approach please see chapter 2.2). This open and direct engagement provided valuable insights into the availability of information on potential Response Indicators, which served as an important input for a survey sent to the Living Lab partners (see chapter 2.2).

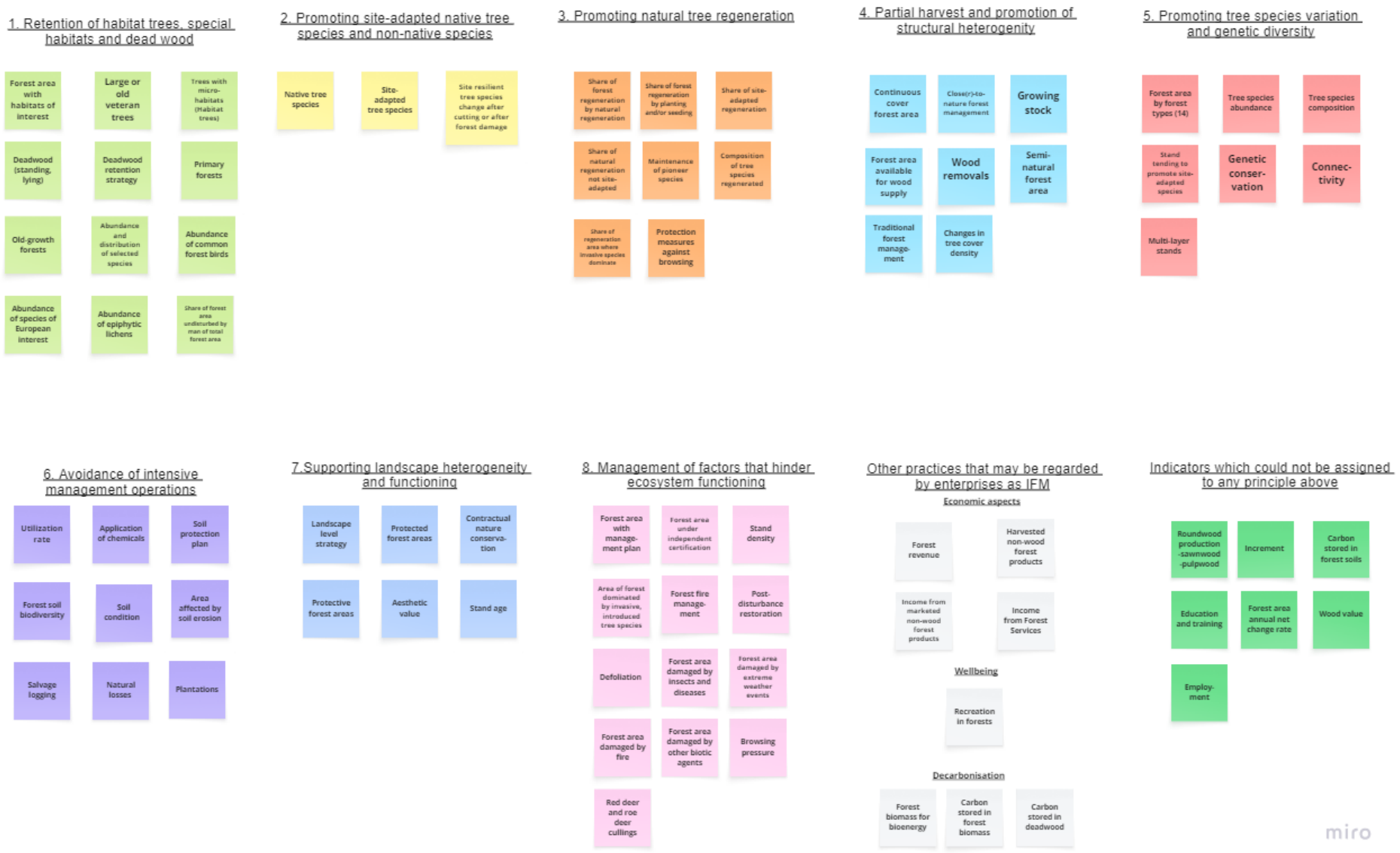


Figure 1. Pool of indicators categorized under the eight IFM principles as defined in WP3 and two additional categories for socio-economic indicators.

2.2 Second Indicator Workshop

The second indicator workshop (Milestone 14) it was intended to reach out to the stakeholders in the Living Labs. At least one person from each of the seven Living Labs[2] with knowledge about their inventory results and data availability was invited to the second indicator workshop, in addition to our group of internal indicator experts (a detailed participants list is in Milestone 14).

The focus of the workshop was on a "reality check" of local data availability and technical challenges for each of the 42 indicators. The aim was to identify and exclude indicators for which no data exists or where data cannot be feasibly obtained due to technical or practical limitations. This step was essential to ensure that the selected indicators are not only theoretically sound but also applicable in real-world settings. For example, while some indicators may be conceptually relevant for IFM, they might require data that is unavailable at the national or local level or would demand significant resources or specialized tools to collect it. By engaging with Living Lab forest managers, we assessed whether the indicators were of practical interest to them and suitable for local-level assessments.

To cluster the indicators, we had chosen the OECD Pressure-State-Response (PSR) Framework suitable to depict the causal chains of IFM related issues (Adriaanse, 1995; Hammond et al., 1995; OECD, 1993) (see Figure 2). The PSR framework is a widely recognized conceptual model used in environmental policy and sustainability assessments (Hagan & Whitman, 2006) and provides a systematic approach for analysing and understanding the relationships between human activities, environmental pressures, the state of the environment, and policy or stakeholder responses. The approach is seen as a relevant tool for structuring communication between scientists, practitioners and stakeholders (Maxim et al., 2009).

Due to limited availability of the participants, we conducted not one but two online indicator workshops on 4 and 5 December 2024 with a total of 22 participants including eight representatives from all our seven Living Labs.

The objective of the workshops was to collaboratively review and further reduce the number of indicators together with the Living Lab representatives. This process was based on information about data availability, technical and spatial uncertainties, and the level of interest in the indicators at hand. During the workshop, we used Zoom's polling feature to gather immediate feedback from participants for each indicator. Specifically, we asked whether the indicator was of major interest, whether the necessary data were available, whether it was feasible to collect, and what difficulties or challenges might arise in collecting the data. The results of the polls were discussed immediately during the workshop, allowing participants to provide additional context and insights. This collaborative process led to the merging of some indicators and the exclusion of others with low data availability. As a result, the total number of indicators was reduced to 28 (for more details see Milestone 14).

On the occasion of a meeting to improve forest biodiversity indicators for Austria, the IFM indicator approach and preliminary indicators were presented and discussed on 19 March 2025 with Austrian forest stakeholders, including environmental NGOs and forest owner representatives as well as PEFC Austria. Their constructive feedback on the relevance of certain indicators, or on feasibility of data collection was incorporated into in the preparations of the third indicator workshop.

[2] https://transformforests.eu/living-labs/

In March 2025, we also conducted a survey that was distributed to all Living Lab representatives. Based on the outcome of the second indicator workshop to include more descriptive Response Indicators into the set, we enquired whether there is a deadwood retention plan, a forest risk management plan, a strategy to adapt to climate change and to increase resilience, a landscape level strategy and a general forest management plan. For each of those plans or strategies we also requested input on the content or on the issues covered by the plan or strategy. The survey was replied by all Living Labs and provided valuable input for the further development of the Response Indicators. The results were discussed with colleagues from UFR, BOKU and EFI both online and during a personal meeting on 28 March 2025, which led to a further condensation of the list to 22 indicators.

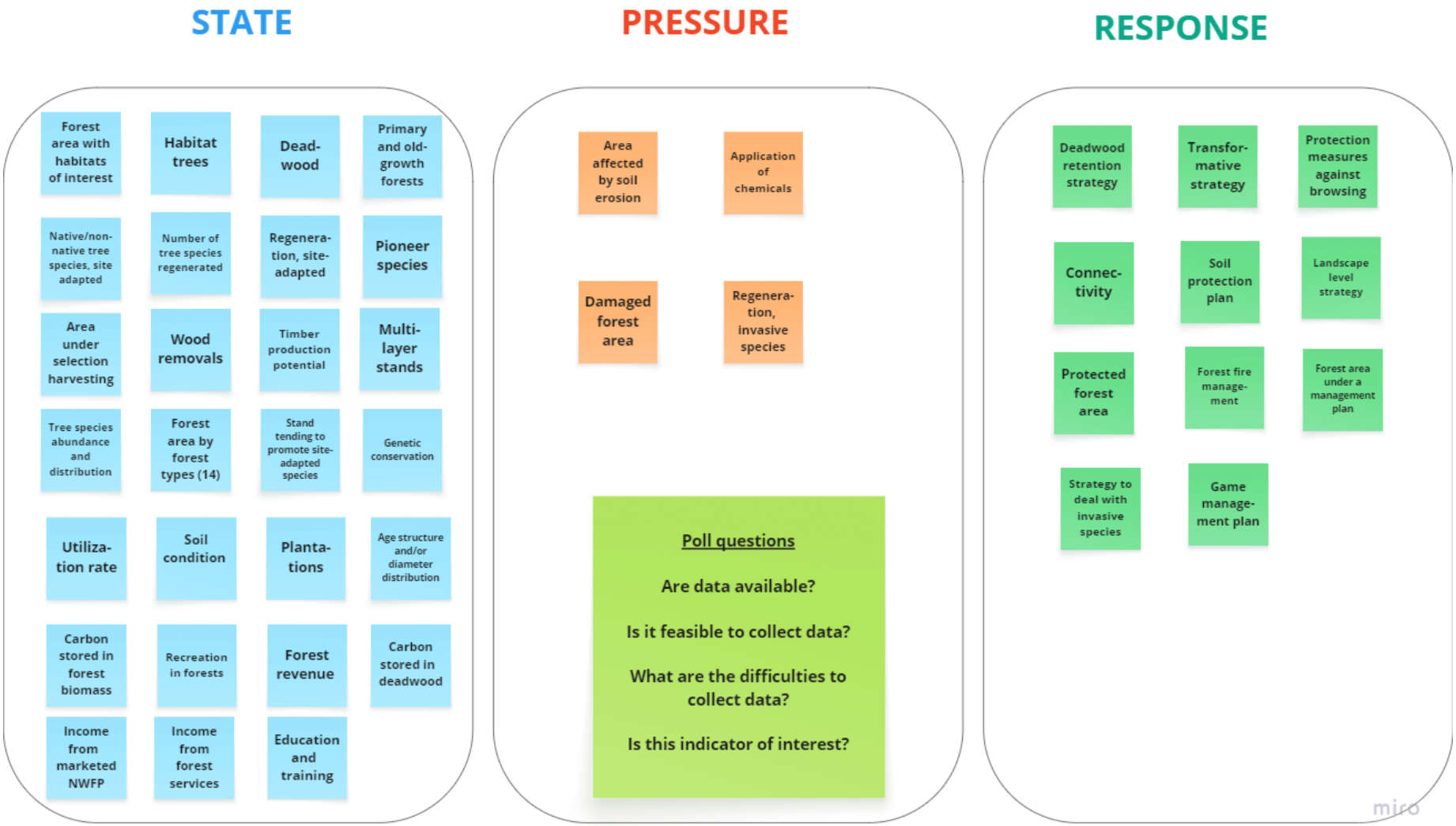


Figure 2. Indicators assigned to Pressure, State and Response categories developed by the Organisation for Economic Co-operation and Development (OECD) and questions asked in the polls.

2.3 Third Indicator Workshop

The final workshop (Milestone 15), hosted by the Croatian project partners in Zagreb on 3 April 2025, was attended in person by 21 participants (a detailed participants list is in Milestone 15). Representatives from all seven TRANSFORMIT Living Labs were present. Croatian stakeholders from environmental NGOs and from the City Forest Administration were invited but were unable to attend due to other obligations.

The 22 indicators were presented in poster format, including detailed metadata. The review process focused on the availability of targets and thresholds derived from international and EU directives and strategies. For indicators without EU targets or thresholds, participants jointly discussed and proposed suitable ones. In the months after the indicator workshop the proposals were further refined and discussed online within the consortium to reach broad agreement. This collaboratively approach lead to the final selection of 17 key indicators for IFM (see Figure 3). These indicators were deemed relevant across all Living Labs and scalable for different contexts and include proposed targets or thresholds. Figure 3 displays the final set of indicators, highlighting a clearly visible causal relationship between them.

By combining scientific approaches, participatory engagement, and policy alignment, this set of indicators provides a robust tool for IFM assessment.

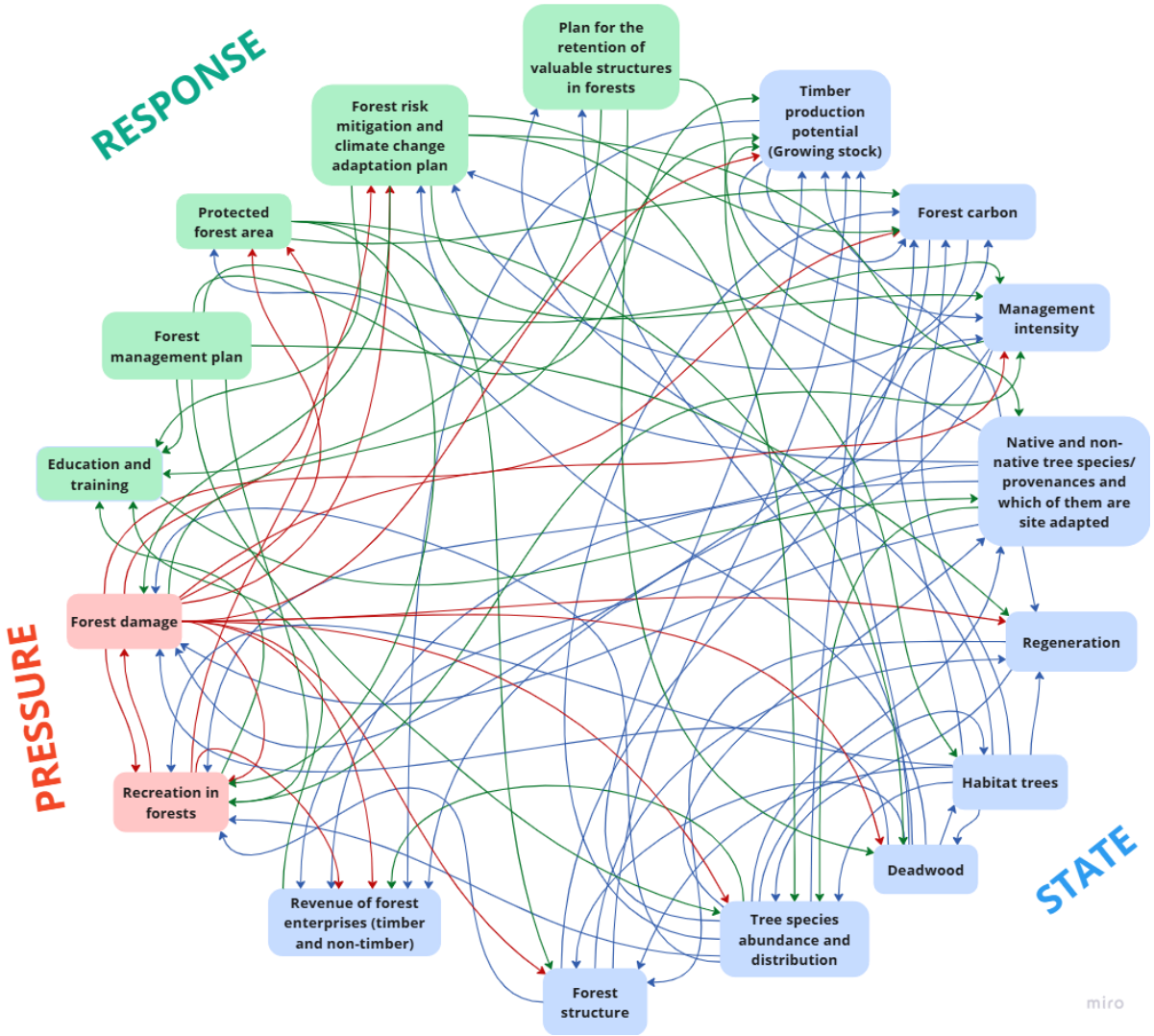


Figure 3. The 17 Key Indicators for IFM and their causal interrelationships.

3. Indicator Factsheets

The 17 key indicators are presented in detailed factsheets, structured according to the goals of IFM (see chapter 1), and are aligned to Forest Ecosystem Services (FES) (see Figure 4).

FES are the benefits that people and nature derive from forests. These services are essential for human well-being, economic development, and environmental health. They are typically categorized along the four Ecosystem Service (ES) categories, i.e. Provisioning, Supporting, Regulating & Maintaining and Cultural, as defined by the Common International Classification of Ecosystem services (CICES) framework (Haines-Young, 2023; Haines-Young & Potschin-Young, 2018; Reid et al., 2005).

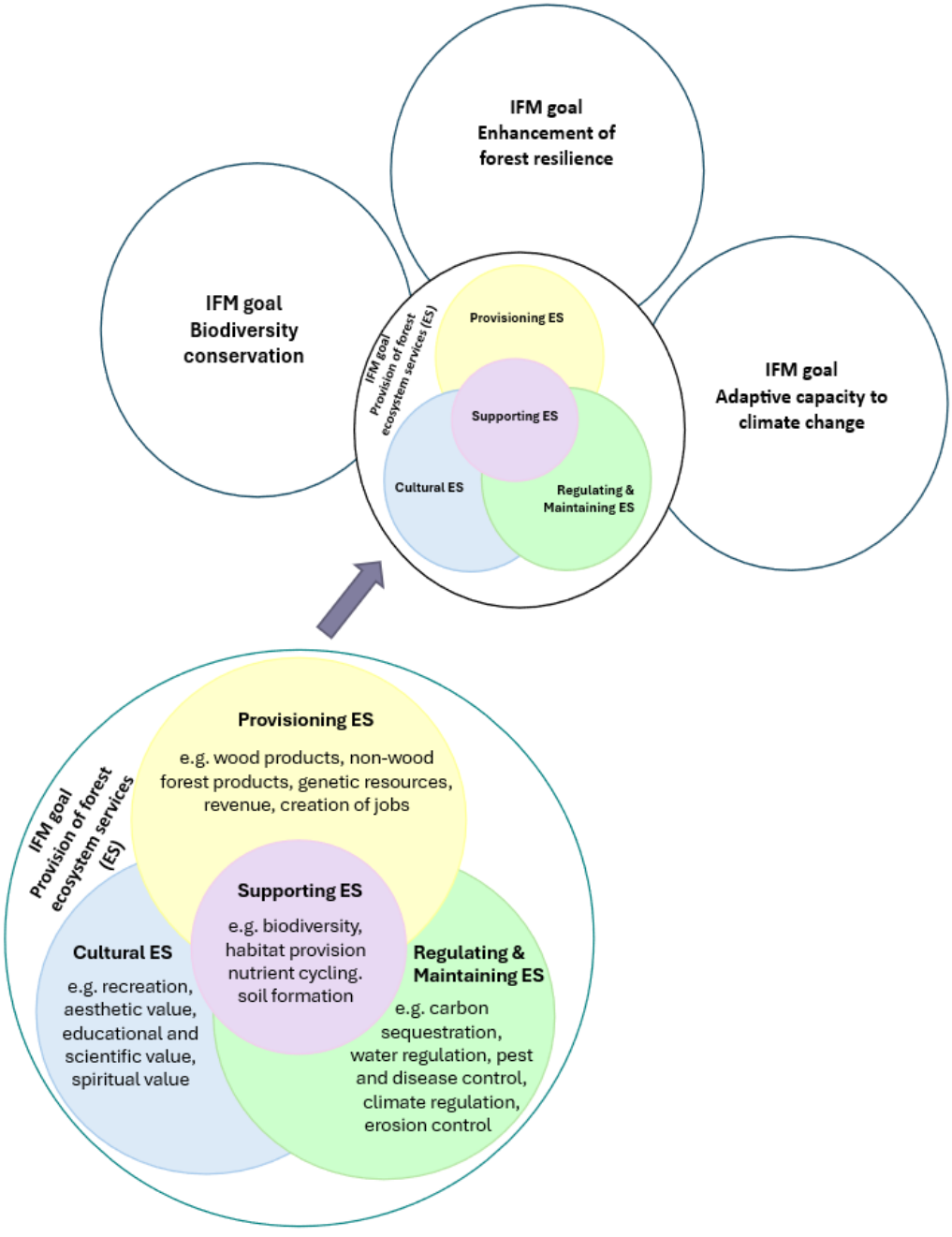


Figure 4. Goals of IFM and the associated ecosystem services as well as an enlarged section with further details on Forest Ecosystem Services.

Each factsheet also contains information on:

- **Characteristics** (Pressure, State, Response indicator) and purpose of each indicator e.g. for reporting, communication, decision-making.
- **Rationales** explaining the importance of each indicator for IFM assessment.
- **Trade-offs** highlighting diverging perspectives or aspects of the indicators.
- **Regionalisation,** describing all available information on regional differences based on the Forest Europe State of Europe's Forest 2020 report (Forest Europe, 2020).
- **Indicator references** listing the corresponding indicators from international indicator sets.
- **Local measurement units,** presenting how the indicator could be measured at the local level (stand or enterprise level).
- **National measurement units,** presenting how the indicator could be measured at the national or regional level.
- **National data sources,** linking to databases where national data is publicly available.
- **Thresholds or targets** presenting related thresholds or targets from EU and other international regulations. Local-level targets or thresholds are also included, which were discussed and proposed by the consortium members, Living Lab representatives and stakeholders during the third indicator workshop, and subsequently reviewed with the enlarged consortium.
- **Direction,** explaining how the indicator value should develop to demonstrate the positive effects of IFM.

By providing information on all the above-mentioned points, the factsheets offer a comprehensive, scalable framework for assessing IFM.

INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Deadwood

IFM goal: Biodiversity conservation

FES: Biodiversity; Habitat provision; Carbon sequestration

Explanation of importance for IFM assessment

Monitoring the presence and quantity of deadwood is an important integrative measure as deadwood enhances structural diversity and provides essential habitat for many, particularly endangered forest species. It can be used as a wood product and depending on the type/dimension is a fuel for potential forest fires. Deadwood contributes to nutrient cycling, carbon storage, water retention, and fosters regeneration on or next to lying deadwood (Bauhus et al., 2018; Hagge et al., 2019; Müller & Bütler, 2010). Monitoring deadwood helps forest managers track changes due to interventions or disturbances and implement proper measures for deadwood enhancement or reduction.

Characteristics

State indicator

Predictor of species diversity of wood-inhabiting fungi and beetles

Can *predict* higher fire risk with increasing climate change depending on type and dimension of deadwood

Reporting on biodiversity aspects

Communicating forest-biodiversity status

Decision-making regarding biodiversity management, habitat preservation, fire precaution

Trade-offs

Fine fuel deadwood might increase fire danger ≠ Large-scale deadwood might inhibit fire danger.

Habitat for endangered species, water retention, carbon sequestration ≠ For pest precaution, it may be necessary to remove high shares of deadwood.

Habitat for endangered species, water retention, carbon sequestration ≠ Fire precaution.

Deadwood retention ≠ Salvage logging.

Safety concerns with standing deadwood next to paths and roads. In some countries, the road keeper is liable for safety on the roads.

Strict forest legislations request spruce deadwood with bark to be removed.

Harvesting standing deadwood is not economically profitable.

Regionalisation

Lying deadwood is the predominant structural component in forests in most countries. Total deadwood ranged in 2015 from 5.8 m³/ha in SW Europe to 18.4 m³/ha in CW Europe. Over the last 25 years, the amount of deadwood increased in all European regions except CE Europe. This increase is highly dynamic, often resulting from increased disturbances.

Indicator references

Forest Europe 4.5

FISE - the Forest Information System for Europe

EU Nature Restoration Regulation

Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests

FSC 6.6.5

Part of Index of Biodiversity Potential

Local measurement units

- Lying and standing deadwood incl. stumps in m³/ha if >10 cm in diameter and by
  - Forest type
  - Coniferous, broadleaved or more detailed tree species
  - Decay classes
- Lying and standing deadwood in percent of the growing stock (%)

National measurement units

Standing deadwood:

- m³/ha by forest type (>10cm in diameter, >1,3 m height)

Lying deadwood:

- m³/ha by forest type (>10cm in diameter)

National-level data sources

NFI

Forest Europe

FAO FRA

Target or threshold and desired direction

EU target: Optimise deadwood retention (Guidelines on Closer-to-Nature Forest Management)

Proposed target: Remain 5-10% of the volume of the growing stock as deadwood in the forest (site and stand age dependent)

Direction: Increasing for natural forest regeneration and forest biodiversity, decreasing for fire precaution.



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Habitat trees

IFM goal: Biodiversity conservation

FES: Habitat for forest species

Explanation of importance for IFM assessment

Habitat trees are usually large, old, living or dead microhabitat-bearing trees that provide essential resources or play a crucial role in the life cycle of many dwelling species in managed forests like beetles, fungi, lichens, bats, small mammals, and insects. Also, younger trees which will be allowed to develop micro-habitats and to reach their senescence can be assigned and conserved as habitat trees. The conservation of trees that are of ecological, cultural or aesthetical interest has a long tradition in European forests and is now systematically applied under integrative approaches in forest management. By identifying and preserving habitat trees, IFM strives to enhance habitat quality, habitat diversity, structural complexity, and compositional heterogeneity in forests, thereby promoting natural tree dynamics (Asbeck et al., 2021; Bütler et al., 2013; Kraus et al., 2016; Larrieu et al., 2022; Mölder et al., 2020).

Characteristics

State indicator

Predictor of species diversity

Reporting on biodiversity aspects and on aesthetic values

Communicating forest biodiversity status

Decision-making regarding habitat tree selection and conservation priorities

Trade-offs

Large habitat trees ≠ High value timber

Stem with microhabitats ≠ High timber value

Potential habitat trees, which are allowed to develop microhabitats in time, are often already large trees, which are economically attractive (Spînu et al., 2022, 2024) and therefore difficult to convince forest owners to leave them developing as habitat trees (LL Catalunya).

Regionalisation

-

Indicator references

Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests

FSC 6.6.5

Part of Index of Biodiversity Potential

Local measurement units

- Number of trees/ha which are harmless from a phytosanitary and safety point of view (for instance, for workers or for visitors, next to hiking paths) with:
  - >40 cm DBH (in boreal forests and in regions where the trees are rather young e.g. after huge disturbances)
  - >45 cm DBH
  - >60 cm DBH
- Number of trees/ha which will be allowed to reach their senescence and form tree microhabitats in the future
- Share of trees older than half of their lifespan (%)

National measurement unit

Number/ha

National-level data sources

NFI

Biodiversity monitoring



Target or threshold and desired direction

Proposed target:

5-10 trees/ha with at least >45 cm DBH (40 cm DBH in boreal forests).

Direction:

Increasing the number of habitat trees at least up to 10 trees/ha for biodiversity maintenance and enhancement (Kraus & Krumm, 2013; Niedermann-Meier et al., 2010).

INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Tree species abundance and distribution

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IFM goals: Biodiversity conservation; Adaptive capacity to climate change

FES: Biodiversity; Habitat provision; Aesthetic value

Explanation of importance for IFM assessment

Monitoring the abundance of tree species provides insights into forest ecosystem dynamics, helping to detect shifts in species dominance, succession patterns, or disturbances like climate change and pest outbreaks. This information is important for IFM decisions, including species selection for regeneration and interventions to maintain ecosystem stability and biodiversity. Assessing tree species also reveals the diversity and complexity of forest habitats. Forests with more tree species are more resilient to disturbances and climate change, offering a range of ecological niches and resources. Economically, species diversity influences market demand and resilience to damaging agents. Additionally, stands with diverse tree species provide ecosystem services such as water regulation, soil stabilization, and recreation, enhancing the socio-economic value of the forest.

Characteristics

State indicator

Predictor of species diversity and forest resilience

Reporting on tree species composition *and distribution*

Communicating forest-biodiversity status

Decision-making regarding species selection and forest management activities (e.g. thinning)

Trade-offs

Climate change-adapted or more diverse tree species ≠ Demand on the timber market

Regionalisation

In Nordic countries and at higher elevations tree diversity is lower than in temperate forest ecosystems.

Indicator references

Forest Europe 4.1

EU Nature Restoration Reg.

Local measurement units

- Share of forest area with
  - 1, 2-5, 6+ tree species occurring (%)
  - shrubs
  - %/spp
- Abundance of each tree species/ha,
- Change of abundance of each tree species
- Dominant tree species/ha
- Shannon Diversity Index
- Gini coefficient

National measurement units

Share of forest area (%) with

- 1
- 2-5
- 6+ tree species occurring
-shrubs

National-level data sources

NFI

Forest Europe

FAO FRA

Target or threshold and desired direction

EU targets:

Promote the mixing of species (Guidelines on Biodiversity-friendly Afforestation, Reforestation and Tree Planting)

Increase tree species richness (including in specific cases the introduction of pioneer species that are more resilient and better adapted to long-term climate change) (Guidelines on Closer-to-Nature Forest Management)

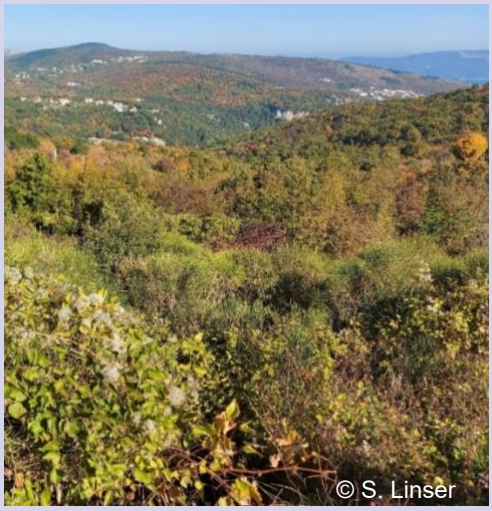
Maintain and increase genetic variation within tree species (Guidelines on Closer-to-Nature Forest Management)

Proposed target:

≥ 3 tree species in each stand (Krumm et al., 2020b; Larsen et al., 2022; WP3/P5)

Direction:

Increase species diversity



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Native and non-native tree species/ provenances and which of them are site-adapted

IFM goals: Adaptive capacity to climate change; Enhancing forest resilience

FES: Biodiversity

Explanation of importance for IFM assessment

Monitoring native and non-native tree species, as well as their provenances and site-adapted characteristics, is important for IFM as native tree species provide essential habitat, food, and shelter for diverse local organisms, contributing significantly to biodiversity and carbon sequestration. Understanding which native species are resilient to climate change helps in selecting trees that enhance the adaptive capacity of forest ecosystems to changing conditions. Site-adapted species, whether native or non-native, are specifically suited to local environmental conditions such as soil type, moisture levels, and elevation. These species can enhance ecosystem resilience and productivity, optimizing tree growth, health, and the provision of ecosystem services (Krumm & Vitkova, 2016). Monitoring these species ensure that forest management practices are tailored to promote ecosystem stability, functionality and wood production. It allows forest managers to make informed decisions about species selection and management strategies.

Characteristics

State indicator

Can predict the adaptability of forest ecosystems to climate change

Reporting on species suitability and site adaptation

Communicating biodiversity status

Decision-making regarding species selection and site-specific management

Trade-offs

Promoting biodiversity and naturalness by prioritizing native tree species ≠ enhancing forest resilience to climate change by introducing site-adapted tree species to secure ecosystem services. While native tree species may not always be the best suited to future climatic conditions, site-adapted species - whether native or non-native - can improve resilience. However, the use of non-native species carries the risk of invasiveness.

Indicator references

EU Nature Restoration Regulation

Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-growth Forests

Part of Index of Biodiversity Potential

Local measurement units

- Area covered (ha)
- Share of area covered (%)
  - native tree species
    - in overstorey
    - in understory
    - site-adapted
  - non-native tree species/provenances
    - in overstorey
    - in understory
    - site-adapted

National measurement units

Area covered (ha)

Share of area covered (%)

-Native

-Non-native/ provenances

-Site adapted

National-level data source

NFI

Regionalisation

-

Target or threshold and desired direction

EU target: Avoid introducing invasive alien species (Guidelines on Biodiversity-Friendly Afforestation, Reforestation and Tree Planting)

Proposed targets

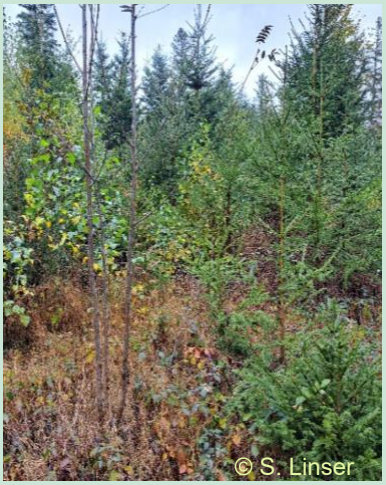
>⅔ of the forest cover consists of native species

>1/3 of tree species in overstory are site-adapted

>2/3 native tree species

<1/3 non-native tree species which should be adapted to site conditions and climate change (Krumm et al., 2020), WP3/P2)

Direction: Increase the share of site-adapted species



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Regeneration

TRANSFORMIT

IFM goal: Adaptive capacity to climate change

FES: Biodiversity

Explanation of importance for IFM assessment

Monitoring regeneration of native or non-native species is essential for IFM as it provides an important ecological and economical background. Site-adapted natural regeneration is cost-effective, fosters self-thinning and leads to uneven-aged, structurally stable, more resilient forests with high carbon mitigation potential (Crouzeilles et al., 2020; König et al., 2022; Zerbe, 2002). However, in areas where natural regeneration may not be successful or is not site-adapted, planting or seeding can be valuable. While costly, planting or seeding help diversify tree species, accelerate stand development, and enable the selection of site-adapted tree species to provide forest ecosystem services in the face of climate change. Planting native tree species to replace non-native natural regeneration (e.g., spruce in Central Europe) is an effective measure to promote biodiversity and naturalness. Fostering site-resilient species/saplings after disturbances, whether naturally regenerating or planted, enhances the forest's ability to sequester carbon and aid ecosystem recovery and resilience, creating healthier, more stable forest ecosystems. Monitoring natural regeneration that is not site-adapted provides critical feedback on potential mismatches between tree species and changing site conditions, impacting forest resilience, carbon sequestration and revenue from the forest. An increase of different tree species in the regeneration layer will lead to more structured, stable and healthier stands.

Characteristics

State indicator

Predictor of species diversity and of adaptability of forests to climate change

Reporting on regeneration success and species composition

Communicating adaptation measures

Decision-making regarding species selection, biodiversity management and adaptation measures

Trade-offs

Natural regeneration is free of costs ≠ Planting is expensive

Natural regeneration is not necessarily site-adapted

Several decades old inventories of the potential natural vegetation are outdated due to climate change

Planting of exotic trees as a chance to economically compensate for the natural decline ≠ risk of biotic invasion (Krumm et al., 2020)

High dominance of invasive species can hinder native tree regeneration

Damage by large ungulates hinder the natural forest regeneration and make any afforestation impossible. This leads to high costs for planting and tree-protecting activities and severely complicates measures for adaptation to climate change (EEA, 2016)

Planting broadleaves is 10 times more expensive than planting conifers (LL Landes of Gascony)

Regionalisation

In all regions except Central-East Europe, more than 60% of the total forest area was established by natural regeneration except in Central-East Europe (48.3%)

Natural regeneration is slightly increasing in all European regions, except in Northern Europe, where planting is most common.

In mountainous and boreal forest eco-systems forests stands are naturally composed of only one to a few different tree species.

National measurement units

Regeneration type (natural, seeded, planted, coppice), site-adapted in ha, %

Share of regeneration area (%) with

- 1
- 2-5
- 6+ tree species or provenances occurring

-shrubs

-dominance of invasive species

National-level data sources

NFI

Forest Europe

FAO FRA

Indicator references

Forest Europe 4.2

FSC 10.2.2

FSC 10.2.5

Local measurement units	**Target or threshold and desired direction**
Regeneration type in ha, share of in %: -natural regeneration -site-adapted -planted/seeded regeneration • native tree species -site-adapted • non-native tree species -site-adapted -coppice sprouting • native tree species -site-adapted • non-native tree species -site-adapted *-invasive* *Number of tree species regenerated:* Share of regeneration area (%) with - 1 - 2-5 - 6+ tree species or provenances occurring - shrubs Share of regeneration area (%)/spp Share of dominant species in the regeneration layer (%)	*EU target:* Promote diversity and natural forest processes (Guidelines on Closer-to-Nature Forest Management, (EC, 2023) *Proposed targets:* • ≥ 3 tree species in the regeneration of each stand (Krumm et al., 2020; Larsen et al., 2022) • >⅔ of the area in mature stands carries advanced regeneration (WP3/P3) • Promote natural regeneration wherever possible, elsewise seeding or planting of site-adapted species. *Direction:* - Decrease invasive species in regeneration until 0% - Decrease non-site-adapted regeneration until 0% - Increase site-adapted regeneration up to 100%



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Forest structure

IFM goal: Enhancing forest resilience; Provision of forest ecosystem services

FES: Biodiversity; Habitat provision; Aesthetic value; Resilience

Explanation of importance for IFM assessment

Information on forest structure combines the assessment of even or uneven-aged age structure and diameter distribution with multi-layeredness. By monitoring stand age and diameter distribution, managers can obtain accurate increment data, enabling timber production planning and sustainable harvest scheduling. Additionally, maintaining diverse vertical structures through a mixture of tree ages and dimensions addresses ecological and economic management objectives like increasing habitat diversity, enhancing resilience against natural disturbances and climate change impacts, improving the quality and value of individual trees, ensuring regeneration, and supporting economic viability by providing optimized, regular revenues while minimizing costs of artificial regeneration (Gao et al., 2014; Messier et al., 2014; Puettmann et al., 2009).

Characteristics

State indicator

Predictor of harvesting capacities and of resilience against natural disturbances

Reporting on forest structure and its implications for biodiversity and resilience

Communicating the importance of structural diversity for resilience and biodiversity

Decision-making regarding structural diversity, and resilience-building measures

Trade-offs

Rich structured forests ≠ economies of scale in harvesting that favour clear-cutting (Aggestam et al., 2020)

Regionalisation

For Europe as a whole, more than 70% of FAWS is reported as even-aged, in which the inter-mediate development phase dominates (>60%), while mature and regeneration phases amount to about 18% each. Uneven-aged forests with multiple layers cover almost 30% of the FAWS area all over Europe. SE Europe has the highest share of forests (47%) where multiple layers may occur. Regions where clear-cutting and replanting are more common in Europe have less uneven-aged forests.

Indicator references

Forest Europe 1.3

EU Nature Restoration Reg.

Guidelines for Defining, Mapping, Monitoring and Strictly Protecting EU Primary and Old-Growth Forests

Part of Index of Biodiversity Potential

Local measurement units

- Age-class distribution in even-aged stands (%)
- Volume (m^3) per age class in FAWS
- Area (ha) per development phase (regeneration phase, intermediate phase, mature phase, unspecified),
- Volume (m^3) per development phases in FAWS
- Diameter distribution in uneven-aged stands
- Volume/ha by diameter class (≤-20 cm; 21-40 cm; >41-60 cm; >60; unspecified)
- Share of shrubs (%)

National measurement units

- Age-class distribution in even-aged stands (%)
- Diameter distribution in uneven-aged stands
- Share of shrubs (%)

National-level data sources

NFI

Forest Europe

FAO FRA

Target or threshold and desired direction

EU target:

Increase structural complexity (Guidelines on Closer-to-Nature Forest Management)

Proposed target:

Multi-layered forest structure on >⅔ of the forest area if compatible with forest fire prevention plans

Direction: Increase structural complexity



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Forest carbon

IFM goal: Provision of forest ecosystem services

FES: Carbon sequestration

Explanation of importance for IFM assessment

The capacity of sequestering carbon is a key metric in forest management, as it enables forest managers to ensure that activities such as thinning or harvesting do not compromise the forest's ability to sequester carbon. Furthermore, an understanding of carbon dynamics in forests is pivotal in achieving a balance between economic objectives and ecological sustainability, thereby ensuring that timber production does not compromise carbon sink capabilities. Moreover, data on carbon sink is integral to the carbon credit market. Forests that effectively sequester carbon can generate carbon credits, which can be sold to offset emissions from other sectors. This provides a financial incentive for IFM practices. Participation in the carbon credit market enables forest managers to generate additional revenue.

Characteristics

State indicator

Predictor of carbon sequestration potential

*Reporting o*n carbon storage and sequestration capacity

Communicating the role of forests in climate change mitigation

Decision-making regarding carbon sequestration strategies and sustainable harvesting practices

Indicator references

Forest Europe 1.4

EU Nature Restoration Regulation

Trade-offs

Carbon sink ≠ Biomass extraction

Carbon sink ≠ Increased disturbance from climate change

Old forest with low C sink strength have typically accumulated much fuel and thus bear a higher risk for uncontrolled fires.

Younger coniferous forests with high C sink strength may have lower crowns and then we may have a higher risk for crone fires.

Policy over-emphasises the use of forests for energy production instead of increasing forest for carbon storage (EASAC, 2017).

Regionalisation

Carbon stored in biomass per ha is the highest in CW and CE Europe, whereas forests in the Southern regions and North Europe contain half of that quantity. Least amounts of dead-wood are available in SW Europe, highest in CW Europe with corresponding C sink capacities.

Local measurement units

Tons C/ha/year) in

- above-ground living biomass
- below-ground living biomass
- deadwood
- forest soils
- litter

National measurement units

Tons C/ha/year in

- above-ground living biomass
- below-ground living biomass
- deadwood
- forest soil
- litter

National-level data sources

Forest Europe

FAO FRA

Target or threshold and desired direction

EU targets: Increase carbon storage …. roll-out of carbon farming practices (New EU forest Strategy 2030, EU Green Deal, LULUCF Reg., UN Paris Agreement, UN Strategic Plan for Forests 2017-2030, Bonn Challenge)

Target at national/European level: Maintain or increase forest carbon sequestration at ≥ 2.5–3.5 t CO_2/ha/year, depending on country and harvest levels, to achieve climate neutrality by 2050 (LULUCF Reg., (Pilli et al., 2022).

National target on total forest sink contribution: Forests should contribute at least 310 Mt CO_2eq/year by 2030 across the EU (Based on EU's 2030 LULUCF target under the "Fit for 55" package).

Proposed target at stand/local level: Maintain or increase living biomass carbon stocks at ≥ 100 tC/ha, depending on the forest type, age, management practices, and regional conditions (Calvin et al., 2023)and if compatible with forest fire prevention plans.

Direction: Increase carbon sink, particularly on landscape level



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Timber production potential (Growing stock on forest area available for wood supply)

TRANSFORMIT

IFM goal: Provision of forest ecosystem services	**FES:** Timber and wood products; Carbon sequestration

Explanation of importance for IFM assessment

By knowing the timber production potential, forest managers can make informed harvesting plannings that meet timber demands without overexploitation. This indicator helps ensure that forests remain productive, while also maintaining critical ecosystem services like carbon sequestration, biodiversity, and soil and water protection. It is particularly important in adapting to climate change, allowing managers to balance growing stock and introduce site-adapted species where needed, ensuring that forests remain resilient, multifunctional, and sustainable over the long term (Mantau et al., 2010).

Characteristics

State indicator

Predictor of harvesting capacities

Reporting on forest productivity

Communicating timber production potential

Decision-making regarding harvesting planning and carbon sequestration strategies

Trade-offs

Increasing growing stock and high canopy closure ≠ maintaining forest clearings and increasing early successional light demanding (rare) species.

Growing stock as a predictor for wood supply is of economic importance for the rural area ≠ conservation goals.

High growing stock/ha may indicate also potential of biodiversity relevant characteristics.

Decrease of growing stock might be necessary for conversion measures to adapt to climate change.

Enhancement of bioeconomy for the replacement of fossil fuels ≠ protection of forests for biodiversity.

Regionalisation

The Central-East and Central-West European regions have the highest growing stock densities.

Central-West Europe has the highest share of forest area available for wood supply (FAWS) (92%), SE Europe the lowest share (53%). The area of FAWS has been increasing since 1990, only in North- Europe has it declined.

Indicator references

SDG 15.2.1

Global Core Set 8

Forest Europe 1.1

Forest Europe 1.2

Local measurement units

m^3/ha

- on FAWS

National measurement units

m^3/ha

- on FAWS

National-level data sources

NFI

Forest Europe

FAO FRA

Target or threshold and desired direction

EU target:

Keep growing stock volume low to minimise economic loss due to disturbances *(Guidelines on Closer-to-Nature Forest Management).*

Proposed target:

10% of the growing stock will not be harvested but will instead be set aside as habitat trees, special habitats, or dead wood *(WP3/P1).*

Direction:

Overall growing stock should increase particularly on landscape level, though on a stand scale there is a limitation to an increase particularly in young stands.



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Management intensity (increment/fellings) in forest area available for wood supply

TRANSFORMIT

IFM goal: Provision of forest ecosystem services	**FES:** Timber and wood products; Carbon sequestration

Explanation of importance for IFM assessment

By monitoring increment/fellings on forest areas available for wood supply, managers can make informed decisions to optimize both economic returns and ecosystem resilience. Monitoring the harvesting and removal of wood, including salvage logging, provides essential information for IFM on economic goals, which must be carefully managed to avoid compromising biodiversity conservation and carbon sequestration. A utilization rate below 100% ensures that timber harvests do not exceed forest growth. However, in cases of natural disturbances or facing the need to adapt to climate change, rates larger than 100% might be acceptable. Management intensity is not related to the area but rather to temporary intensity, which can vary periodically. High management intensity could be regular every few years, allowing for adaptive management practices that respond to changing conditions. Monitoring these rates helps forest managers assess the balance between timber production and ecological sustainability, ensuring that harvesting practices do not compromise forest health, biodiversity, or carbon sequestration.

Characteristics

State indicator

Reporting on forest productivity

Predictor of sustainable harvesting levels

Reporting on forest productivity

Communicating sustainable harvesting practices

Decision-making regarding harvesting intensity

Trade-offs

High management intensity ≠ Biodiversity conservation goals

Carbon sink in forests ≠ Fellings

There is an increased pressure for increased timber production under global changes and substitution of steel, concrete and fossil fuels.

Retention of deadwood and habitat trees are important parts of any IFM intervention to be considered

Regionalisation

The utilisation rate was highest in North Europe and Central-West Europe, and lowest in South-East Europe

Indicator references

Part of Global Core Set 9

Forest Europe 3.1

FSC 5.2.2

FSC 5.2.4

Local measurement units

- m^3/ha (increment)
- m^3/ha (fellings)
- Share of increment harvested (%)
- Selected harvesting
  - Single tree
  - Group selection
  - Shelterwood systems

-Clearcutting <1 ha

-Clearcutting >1 ha

-Salvage logging

National measurement units

- m^3/ha (increment)
- m^3/ha (fellings)
- Share of increment harvested (%)

National-level data sources

NFI

Forest Europe

FAO FRA

Target or threshold and desired direction

EU targets:

- Ensure that the share of forest-based bioenergy … remains within the limits of sustainability (New EU Forest Strategy 2030)
- Increase domestic wood production (New EU Forest Strategy for 2030)

Proposed target:

<100%, with exceptions (Mönkkönen et al., 2024; Nabuurs et al., 2018)

Exceptions: e.g. damaging events, conversion measures



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Revenue of forest enterprises

TRANSFORMIT

IFM goal: Provision of forest ecosystem services

FES: Revenue of forest enterprises

Explanation of importance for IFM assessment

Revenue from timber and non-timber products is crucial for integrated forest management in forest enterprises because it supports economic sustainability while promoting the provision of various ecosystem services. Timber sales provide core income for investments in sustainable practices, while mainly extensively produced NWFPs such as fruits, mushrooms, or game diversify revenue streams and support regional demand. Additional income from services like clean water, hunting licenses, recreation, and entrance fees to cultural or recreational sites further enhances economic resilience. By balancing income generation with the maintenance of ecosystem services, IFM strengthens the viability of forest enterprises, supports local economies, and promotes long-term ecological and social benefits.

Characteristics

State indicator

Predictor of economic sustainability and forest enterprise viability

Reporting on economic aspects of IFM

Communicating the economic benefits of IFM

Decision-making regarding income generation strategies and balancing economic and ecological goals

Trade-offs

Forest visitors take NWFP and services granted for free ≠ willingness to pay.

Maximizing several ecosystem services simultaneously within a single stand or enterprise ≠ inherent trade-offs between different ecosystem services (Kraus & Krumm, 2013).

IFM can cause lower revenues and additional costs as for example, by preserving old trees and leaving large amounts of deadwood in the forest. Additional costs can also arise when applying more expensive timber harvesting methods to support soil protection (Krumm et al., 2020).

Money from the timber pays for biodiversity conservation (LL Landes of Gascony).

Regionalisation

The main share of factor income was generated in North and Central-West Europe (Data availability for other countries was low).

Data quality on NWFP and services is too low for valid regional assessments.

Indicator reference

Forest Europe Indicators 3.3, 3.4, 6.3

EUROSTAT

UNECE

Local measurement units

EUR/ha for
- -timber products
- -NWFP
- -services
- -other

National measurement units

EUR/ha for
- -timber products
- -NWFP
- -services

National-level data source

Forest Europe

Target or threshold and desired direction

EU target:

An increase of revenue should lead to the economic viability and sustainability of forest enterprises (Aggestam et al., 2020; EC, 2021; Krumm et al., 2020).

Proposed target:

Forest owners should get fair prices for products from their forests that exceed costs for management and harvesting. This also accounts for small scale owners that however might be organised in associations or similar to effectively deal with the cost

Direction: Increase of revenue



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Disturbed or damaged forest area

IFM goal: Enhancing forest resilience

FES: Resilience; Biodiversity; Carbon sequestration

Explanation of importance for IFM assessment

Monitoring forest disturbance and damage is essential for IFM as it enables timely and effective responses to threats. IFM can mitigate disturbances or damages through integrated damage management practices, which include promoting diverse forest structures and site-adapted, mixed tree species compositions. Such diversity enhances ecosystem resilience, making forests less susceptible to abiotic and biotic threats. Regular monitoring allows forest managers to detect early signs of disturbance or damage, assess the severity, and implement appropriate interventions promptly (Patacca et al., 2023). This proactive approach not only guards forest health and productivity but also biodiversity and other ecosystem services.

Characteristics

Pressure indicator

Can *predict* higher disturbances or damages with increasing climate change

Reporting on forest ecosystem health

Communicating forest pressures through disturbance or damage

Decision-making regarding damage mitigation and resilience-building measures

Trade-offs

Accepted natural disturbance (tree mortality) ≠ Damage (monetary or socio-cultural impact of disturbance on human values)

Damaged forest area ≠ Timber production

Damaged forest area ≠ Ecosystem services provision

Clear-up damaged areas and reforest with site-adapted species as fast as possible ≠ Wait for native/site-adapted natural regeneration

Regionalisation

Damages by storm, wind and snow mainly affect the North, South-East and Central-East European regions.

Large forest fires mostly affect the Mediterranean region.

Forest area damaged by wildlife was highest in North Europe and lowest in South-East Europe.

Extensive forest dieback caused by bark beetle outbreaks in Central Europe.

Indicator references

Global Core Set 6

Forest Europe 2.4

Local measurement unit

Area (ha) and share of forest area disturbed/ damaged (%) by:

- insects and diseases
- extreme weather events
- fire
- other biotic agents like wildlife and grazing

National measurement units

Area (ha) and share of forest area (%) damaged by:

- Insects and diseases
- extreme weather events
- fire
- other biotic agents

National-level data sources

NFI

Copernicus C3S Burnt Area dataset

DFDE, Database on Forest Disturbances

EFFIS, European Forest Fire Information System

Forest Europe

ICP Forests (for defoliation)

INForest Database

Landsat satellites

Target or threshold and desired direction

EU target:

Reduce deforestation and forest degradation (Deforestation Regulation, EP and Council, 2023).

Proposed threshold:

>10% forest area affected = damaged forest area with potential economic and habitat loss (Köhl et al., 2024; Robertson et al., 2024).

Direction: Decrease damaged forest area through IFM to avoid economic and habitat loss.



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Recreation in forests

TRANSFORMIT

IFM goal: Provision of forest ecosystem services	**FES:** Recreation; Aesthetic value
Explanation of importance for IFM assessment Tourism and income from paid services can significantly contribute to forest owners' incomes. However, tourism and recreational uses increasingly put pressures on forest owners, forest ecosystems and wildlife. Threats to forest biodiversity from tourism include the use of bikes off-road, skiing off-slope, the round-the-clock/nonstop presence of recreationalists in forests, damage of regeneration, littering and excessively collecting non-wood forest products. Forests with tall and old trees are preferred by recreationalists and generate high recreational values (Giergiczny et al., 2021) but might generate less revenues from harvesting if social pressure is put on forest owners to omit harvesting activities. In some countries forest owners are responsible for the safety of roads and paths and might have high additional expenses to remove dead branches and unstable stems to ensure visitor safety.	**Characteristics** *Pressure indicator* Can *predict* higher pressure on forest ecosystems with increasing number of recreationalists *Reporting* on recreational use and its impacts *Communicating* forest pressures through access for leisure *Decision-making* regarding balancing recreational use and IFM goals

Trade-offs	**Regionalisation**	**Indicator reference**
Use of wood ≠ Recreational and aesthetic values Valuable structures in forests ≠ Safety of visitors Open forests can enhance both recreational opportunities and biodiversity, but this often requires active management, such as cutting trees.	In North Europe, almost all forests are available for public recreation, in CW and CE Europe it is more than half and in Southern Europe it is less than 40%.	Forest Europe 6.10

Local measurement units	**National measurement units**	**National-level data sources**
Public access to forest area (ha, %) for - hiking, - biking, horse riding, cross-country skiing, others - Expenses to provide services (EUR/ha) - Expenses to remove litter and damages (EUR/ha) - Loss of income (EUR/ha) - Earnings from recreationists (EUR/ha) - Length of pathways that require specific management activities to guarantee security	- Forest area with access for the public in ha; - Share of forest area in % - Earnings from recreation in EUR and EUR/ha - Expenses for the compensation of the various pressures in EUR/ha	Some NFI Forest Europe

Target or threshold and desired direction

EU Target: Access limitations to sensitive nature conservation areas (EC Guidelines on Closer-to-Nature Forest Management, EC, 2023)

Proposed targets:

- Access limitations to sensitive habitats like protected forest areas, regeneration areas and old-growth forests

-Implement visitor guidance tools

-Compensation payments for management for recreation purposes

Direction: Decrease pressure from recreation



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Forest management plan

TRANSFORMIT

IFM goals: Provision of forest ecosystem services; Biodiversity conservation; Enhancing forest resilience; Adaptive capacity to climate change

FES: Stewardship

Explanation of importance for IFM assessment

IFM is typically documented in a forest management plan that outlines the objectives and practices for IFM including ecological (e.g. reducing fragmentation, increasing connectivity), economic (e.g. sustainable harvesting), and social (e.g. staff health care, recreational use) considerations. These plans serve as a critical tool for guiding the implementation of IFM, ensuring that forest management aligns with sustainability goals while balancing multiple ecosystem services and stakeholder interests. In an ideal case, a forest management plan should incorporate additional objectives from other sectors, such as nature conservation and urban planning, to reduce the risk of trade-offs and conflicts.

Characteristics

Response indicator

Predictor of management effectiveness

Reporting on management objectives and practices

Communicating about management activities and forest inventory details

Decision-making about management measures

Trade-offs

Management plans may have trade-offs with plans with different objectives, like plans for nature conservation or plans for urban development that exist in the same area.

Large unfragmented forest areas are beneficial for biodiversity, but a forest management plan must also consider creating fragmentation, if necessary, to help regulate forest fires, bark beetles and pests spreading over larger areas.

Regionalisation

In South-East Europe nearly 100% of the forest area are under management plans, in North Europe 88%, South-West Europe has the lowest share.

Indicator references

SDG 15.2.1

Global Core Set 19

Forest Europe qualitative Indicator under Criterion 3

FSC 7.1.2

Local measurement units

Plan or equivalent with following planned measures:

- IFM as management objectives
- Planned thinning operations
- Planned harvesting operations
- Regular monitoring of standard forest parameters
- Identification of ecologically sensitive or valuable area for special management
- Active management of protected forest areas
- Promote or restore forest ecosystem connectivity and avoid fragmentation

National measurement unit

Share of forest area with forest management plan available

National-level data sources

NFI

National Forest Reports

Forest Europe

Target or threshold and desired direction

EU target:

The share of forest areas covered by forest management plans should cover all managed public forests and an increased number of private forests. (New EU Forest Strategy 2030)

Proposed target:

Management plan or equivalent in place for forest areas >10 ha and which contains > ⅔ of the measures.

Direction: Increasing shares of forest areas covered by plan or equivalent covering > ⅔ of the measures.



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Forest risk mitigation and climate change adaptation plan

TRANSFORMIT

IFM goals: Enhancing forest resilience; Adaptive capacity to climate change

FES: Stewardship; Pest and disease control; Erosion control; Genetic diversity

Explanation of importance for IFM assessment

A forest risk management planning is essential for maintaining forest health, resilience, and productivity and should consider precautionary measures and countermeasures to address risks aligning with conservation and economic objectives (Krumm et al., 2020). The climate change adaptation planning should go beyond changing forestry practices to new site conditions. New objectives and structures must be defined to enhance the resilience and adaptability of forests to new, often unpredictable environmental realities.

Characteristics

Response indicator

Predictor of forest resilience and adaptive capacity

Reporting on planned risk mitigation and adaptation measures

Communicating the importance of planned risk mitigation, preventive and adaptation measures

Decision-making regarding priorities on countermeasures, preventive measures or adaptation measures

Trade-offs

Risk mitigation and climate change adaptation activities might be resource intensive and costly.

Precautionary and containment activities may have unintended environmental impacts like deadwood removal for risk reduction.

Disturbances may provide temporary habitats for a high number of species, depending on size and intensity of affected area (Kraus & Schuck, 2017).

Regionalisation

Southern European countries have already advanced fire management systems due to their history of forest fires and the associated risks.

Local measurement units

Plan or equivalent with following measures:

- Regular monitoring of presence and spread of invasive species, calamities, diseases and other damaging agents
- Precautionary and containment activities (mechanical, chemical, biological)
- Implementation of anti-soil erosion measures to prevent soil degradation
- Measures to reduce game and cattle damages
- Application of forest management practices to enhance resilience and adaptability to new environmental realities incl. transformation of high-risk stands
- Monitoring of stands requiring regeneration and regeneration planning
- Tending and thinning to promote site-adapted tree species
- Tending and thinning to enhance the diversity of tree species e.g. by promoting minority or pioneer tree species
- Restoration of degraded forest ecosystems.

National measurement units

- Share of forest area with activities conducted within the last 10 years:
  - National soil survey
  - National forest risk monitoring
  - Large-scale forest site classifications as basis for site-adapted forest management.
- RS application available to detect forest risks like forest fires, storm damages or defoliation.
- Availability of air force to combat forest fire.
- International co-operation on forest fire fighting.

Indicator reference

-

National-level data sources

- National Forest Strategy
- Respective ministries or agencies

Target or threshold and desired direction

Proposed target:

> ⅔ of the area covered by a plan or equivalent which contains > ⅔ of the measures covered.

Direction:

Plan or equivalent available for the whole forest area covering > ⅔ of the measures.



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Plan for the retention of valuable structures in forests

TRANSFORMIT

IFM goal: Biodiversity conservation

FES: Habitat provision; Biodiversity; Aesthetic value; Stewardship

Explanation of importance for IFM assessment

Retaining valuable structures like bushes, pioneer species, deadwood and habitat trees is ecologically important as these elements provide essential habitats for a wide range of species. Deadwood is a critical resource for decomposers that recycle nutrients back into the soil, enhancing forest health and productivity. Bushes and habitat trees offer nesting sites and food sources. Planning for deadwood retention can also help avoid or reduce salvage logging, which often disrupts habitat creation and ecological processes. While retaining or creating these valuable structures may require short- to mid-term investments, the long-term benefits are significant. Structurally diverse and vital forests are more resilient to threats such as climate change, pests, and diseases. Economically, these investments pay off in the long term by more resilient forest ecosystems safeguarding timber resources and reducing the costs of managing degraded forests. Socially, structurally diverse forests offer recreational opportunities and aesthetic values, contributing to human well-being.

Characteristics

Response indicator

Predictor of biodiversity and habitat quality

Reporting on structural diversity and habitat provision

Communicating to care about valuable structures in forests

Decision-making regarding retention priorities

Trade-offs

Deadwood retention ≠ Salvage logging to increase resilience against bark beetles and forest fires.

Retaining valuable structures in forests may reduce short-term revenues from timber.

Regionalisation

-

Indicator reference

-

Local measurement units

Plan or equivalent with following planned measures:

- Regular monitoring of deadwood
- Retaining deadwood crowns, low-quality stems, branches and stumps after thinning or harvesting
- Designation of zones where any deadwood removal is prohibited if compatible with fire prevention plans
- Designation of habitat trees

National measurement units

Share of forest area with activities conducted within the last 10 years:

- Deadwood monitoring
- Designation of habitat trees (at least 5/ha)

National-level data sources

- NFI
- National Forest Strategy
- National Biodiversity Strategy

Target or threshold and desired direction

Proposed target:

> ⅔ of the area covered by a plan or equivalent which contains > ⅔ of the measures.

Direction:

Plan or equivalent available for the whole forest area covering > ⅔ of the measures.



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Protected forest area (designated by law or by voluntary temporary contracts to protect biodiversity or other forest ecosystem functions)

TRANSFORMIT

IFM goals: Biodiversity conservation; Provision of forest ecosystem services

FES: Stewardship; Biodiversity; Habitat provision

Explanation of importance for IFM assessment

In legally protected forest areas (PFA) but also in forest areas under voluntary contractual nature conservation where harvesting is restricted, IFM may focus on conservation measures to maintain and enhance biodiversity and other ecosystem functions.

Temporary contractual nature conservation fosters collaboration between forest owners, forest administration, research and environmental NGOs incentivising the temporary (usually 20 years) decommissioning of high-value forest areas to conserve biodiversity.

Characteristics

Response indicator

Predictor of species diversity and ecosystem functions

Reporting on protected areas and conservation measures

Communicating the importance of protected areas

Decision-making regarding conservation management

Trade-offs

Unmanaged protected forest ≠ Managed forests with timber extraction

Establishment of additional protected areas ≠ Reduced forest available for wood supply (FAWS) with competing management goals (Kraus & Krumm, 2013)

Protective forests (which need to be managed to maintain their protective functions) ≠ Protected forests

Regionalisation

The protection of forest biodiversity varies considerably within Europe: while minimal or no intervention in PFA dominate in NE and SW Europe, larger PFA with active conservation management are in CE. Forest areas protected for landscapes and specific natural elements are mainly in CW Europe

Contractual nature conservation is primarily a privilege of wealthier European regions, as only richer countries have funds to provide compensation payments.

Most of the designated protective forest stands are in mountainous areas.

Indicator references

SDG 15.2.1

Global Core Set 4

Forest Europe 4.9

SEBI 007

FSC 6.5.4

Local measurement units

Area (ha) and share of forest area (%) set aside through:

- national designation or protection
- voluntary, temporary contracts

National measurement units

Area (ha) and share of forest area (%) set aside through:

- national designation or protection
- voluntary, temporary contracts

National-level data sources

NFI

National Forest Reports

Forest Europe

Target or threshold and desired direction

EU targets:

Legally protect a minimum of 30% of the EU's land area and strictly protect at least a third of the EU's protected areas (EU Biodiversity Strategy for 2030)

Protect all remaining EU primary and old-growth forests (EU Biodiversity Strategy for 2030, New EU Forest Strategy 2030)

Proposed targets:

- Set aside 5% forest area <100 ha
- Set aside 10% forest area >100ha

Direction: Protect the ecologically valuable forest ecosystems, e.g. according to Habitats Directive Annex 1



INDICATORS FOR INTEGRATIVE FOREST MANAGEMENT

Education and training

TRANSFORMIT

IFM goal: Provision of forest ecosystem services	**FES:** Educational and scientific value
Explanation of importance for IFM assessment Education and training of the workforce are essential for IFM because they equip the staff with the knowledge and skills to apply integrative management practices which facilitate to adapt to climate change and conserve biodiversity among other ES. Trained staff can also effectively use advanced/new technologies, comply with regulations, and engage with stakeholders to manage ecosystem services and to balance the IFM goals.	**Characteristics** *Response indicator* *Predictor* of quality of forest management *Reporting* on social aspects and workforce development *Communicating* the importance of education and training for sustainable forest management *Decision-making* regarding workforce development and capacity-building initiatives

Trade-offs	Regionalisation	Indicator reference
-	--	-
Local measurement units - Training days/year/full-time staff equivalent - Presence of adequate facilities (Marteloscopes etc.) - Expenses for forest enterprise in EUR/year	**National measurement units** Publicly offered education and training programmes for forest workforce (Training days/person/ year)	**National-level data sources** - Chamber of Agriculture - Forest training centres
Target or threshold and desired direction *Proposed targets:* - All employees take part in regular education and training programmes - 2-5 days/year as paid work *Direction* Life-long learning		

4. Innovative elements of the Key Indicators for IFM

The development of the key indicators for IFM introduces several innovative elements that enhance forest management assessment. These innovative elements comprise:

1. Holistic and scalable framework

The indicators are designed to address the multifaceted goals of IFM, integrating biodiversity conservation, ecosystem service provision, and climate adaptation. Their scalability ensures applicability from local to national and European levels, making them versatile tools for diverse forest management contexts.

2. Stakeholder-driven process

The bottom-up approach, involving Living Lab forest managers, stakeholders, and researchers, ensures that the indicators are grounded in practical and regional realities. This participatory process fosters ownership and alignment with local needs, enhancing the likelihood of successful implementation.

3. Target-related assessment

The inclusion of targets and thresholds derived from international, and EU Directives, Strategies and Guidelines provides a robust framework for monitoring progress toward policy goals. This alignment with global and regional strategies ensures the indicators' relevance and utility for reporting and decision-making.

4. Innovative solutions for small-scale forests

At the third indicator workshop, it was agreed that IFM, as defined, is best applied to areas larger than 10 hectares. While smaller areas may face challenges in applying IFM practices - such as implementing varying management intensities, silvicultural concepts, protected forest areas, or old-growth islands - they can still play a critical role at the landscape level. Smaller forest areas can act as stepping stones, linking larger forest entities and contributing to landscape-scale connectivity. However, for measures within an individual forest enterprise the minimum area remains a critical aspect, as smaller areas may lack the capacity to implement the full range of IFM practices. To address this, innovative solutions, such as a "small-scale certificate," could be explored to enable the application of IFM principles in smaller forest areas, particularly when they are part of a larger association or IFM management framework.

5. Decision support integration

The indicators were also designed to feed into the selection and adaptation of Decision Support Tools (DSTs) in WP6, enabling forest managers to make informed decisions based on robust, evidence-based information.

5. Abbreviations

Abbreviation	Full text
C&I	Criteria and indicators
CBD	Convention on Biological Diversity
CE	Central-East
CICES	Common International Classification of Ecosystem Services
CW	Central-West
DST	Decision Support Tool
EC	European Commission
NGOs	Non-Government Organization
ES	Ecosystem Services
EU	European Union
EUR	Euro
FAWS	Forest area available for wood supply
FES	Forest Ecosystem Services
FSC	Forest Stewardship Council
ha	hectare
IFM	Integrative Forest Management
LL	Living Lab
NFI	National Forest Inventory
NTFP	Non-timber forest product
PEFC	Programme for the Endorsement of Forest Certification Schemes
SDG	Sustainable Development Goal
SEBI	Streamlining European Biodiversity Indicators
SW	South-West
UN	United Nations
WP	Work package

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