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Forest EcoValue

TRANSNATIONAL COLLABORATION REPORT ON ECOLOGICAL / ECONOMIC VALUATION OF FOREST ECOSYSTEM SERVICES

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Carbon neutral and resource sensitive Alpine region
SO 2.2: Promoting the transition to a circular and resource efficient
economy

**Forest EcoValue:
Supporting multiple forest ecosystem services through new
circular/green/bio markets and value chains**

Project ID: ASP0100005

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List of abbreviations

AT	Austria
AUV	Adjusted Unit Value
AUV₁	Adjusted Unit Value based on Alpine average
AUV₂	Adjusted Unit Value based on local / national primary studies
CO₂	Carbon Dioxide
DE	Germany
ES	Ecosystem Service
FES	Forest Ecosystem Service
FR	France
ha	Hectare
IT	Italy
LL	Living Lab
SI	Slovenia
TEV	Total Economic Value

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1. Introduction

According to the application for the Forest EcoValue project this report is on lessons learnt in living labs from activity 2.2 and activity 2.3, about good practices, DO's and DONT'S deriving from the transnational collaboration among PPs in the Pilot Action as well as with EUSALP and AC WG MF. Also, the transnational exchange between project partners on their experiences in the living labs will be addressed.

According to this objective this deliverable represents the summary of the activities related to biophysical and economic assessment carried out in the Living Labs and lessons learnt from the different living labs, the main weaks and success factors and a reflection on the action which institutions within EUSALP and Alpine Convention might take on board.

Therefore, this report gives in chapter 3 a brief introduction to the five Living labs and then provides an overview in chapter 4 about the forest ecosystem services tackled in this project, which is deepened for each forest ecosystem service in extra chapters for its biophysical and its economic assessments in each living lab. Based on these experiences transnational conclusions are drawn. Finally, chapter 5 gives an insight to the different business models developed in the living lab areas, and finally conclusions for the transnational collaboration with different institutions in the Alpine Convention and EUSALP are drawn. In chapter 6.

2. Project overview

Forests of the Alpine Space play a key role in climate change mitigation and resilience, providing multiple ecosystem services (ES) and environmental and social benefits such as CO₂ absorption, air pollution reduction, biodiversity enhancement, and protection against natural hazards. However, they are threatened by abandonment, climate change, and territorial degradation, which progressively reduce natural resources and the provision of forest ES (FES). Maintenance costs of Alpine forests are high, and public funds and traditional wood value chains are insufficient to cover them. Economic valuation and payment schemes for FES are widely discussed but rarely successfully applied.

The Forest EcoValue project addresses this challenge by developing innovative, sustainable business models for forest management and maintenance, supporting new bio-based value chains and ES markets, and involving different sectors, public and private actors, and citizens. Restoring and maintaining healthy forests has been recognised as a source of value for the Alpine region, while also creating business opportunities and green jobs for Alpine communities.

The project focuses on a subset of FES from the following categories:

- **Provisioning** (e.g. biomass, raw materials, chemicals) with a specific focus on non-timber forest products, and on the production of woody biomass for energy, integrated into circular energy markets.
- **Regulating** (e.g. biodiversity, natural risk reduction, CO₂ absorption) concretely working on carbon and biodiversity credits, natural risk management through protective forests, and innovative environmental finance instruments such as green bonds and reverse auctions.
- **Cultural** (e.g. recreation, habitat experience, health) particularly enhancing recreational and tourism services and spiritual and cultural services.

These services have been explored and tested within Living Labs (LLs) across five countries, located in different Alpine territories and representing diverse ecological and socio-economic contexts:

- **Italy – Valle Tanaro, Piedmont:** The LL in Valle Tanaro explores innovative approaches to valorising chestnut groves, promoting non-timber forest products, developing carbon and biodiversity credits, and fostering experiential activities linked to forest and rural heritage.
- **France – Haute-Savoie:** Grand Annecy and Thonon LLs focus respectively on two aspects 1) recreational ecosystem services, enhancing the value of forests through the sale of experiences such as ecotourism, outdoor activities, and educational programmes 2) enhancing the value of water regulation services through a public-private partnership.
- **Slovenia – Karavanke Mountains, municipality Tržič:** The Slovenian LL addresses natural risk management with a focus on torrent control, advances solutions for wood biomass supply chains and promotes sustainable tourism and recreational use of forests.
- **Austria – Province of Styria:** The Styrian LL concentrates on biodiversity and habitat provision and carbon sequestration and storage through innovative financing mechanisms such as reverse auctions.
- **Germany – Tegernsee Valley, Upper Bavaria:** The German LL explores spiritual and cultural services, such as forest cemeteries with biodegradable urns, while also fostering habitat and biodiversity conservation through collaborative public-private partnerships.

Accordingly, the project is aiming to:

- Map and analyse the Alpine Space forests delivery capacity of FES;

- Identify and estimate the economic potential, define business models and FES market frameworks;
- Test the models/tools developed by the consortium in pilot LLs involving local players;
- Compare results at transnational level, identifying obstacles and facilitating factors;
- Analyse the need for innovative policies to foster forest maintenance, FES markets, and new value chains;
- Elaborate refined transferable tools/models and policy proposals to enable new markets and value chains and ensure the expected FES.

Throughout the project, a continuous participatory process is carried out within the Living Labs. Stakeholders' active involvement in these labs is essential for co-designing and testing models and tools, ensuring that the innovative approaches are rooted in local realities. In parallel, public events and capacity-building workshops have strengthened engagement, supported knowledge transfer, and provided regular updates on project activities. This participatory and long-term approach, tested across the five territories, is paving the way for refined, transferable tools and policy proposals that can unlock new markets and value chains while safeguarding the provision of ecosystem services in the Alpine Space.

Project duration: 42 months

3. Overview of Living Labs

The living lab areas which were used as pilot areas had – due to framing conditions in the different countries – different size and forest composition. A first overview of the forest area in the living labs is presented in Figure 1. Further information is provided in chapter 4.

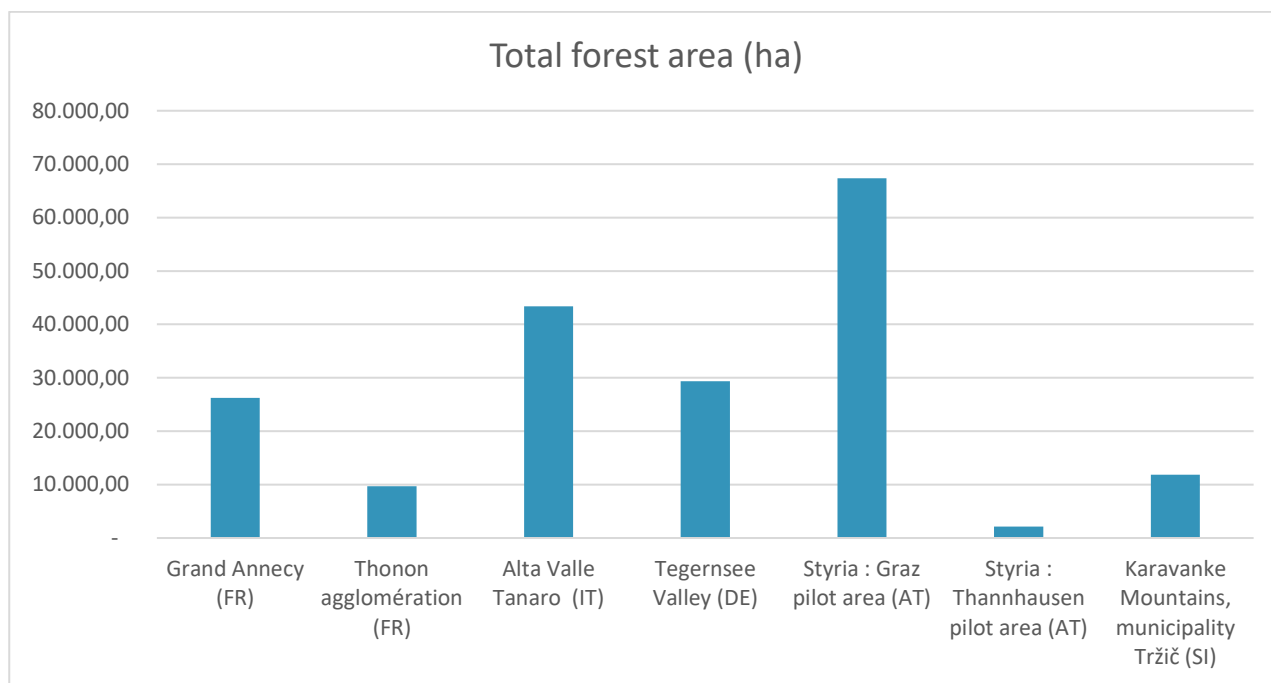


Figure 1: Total forest area for the Living labs.

3.1 Austria

The Austrian Living Lab adopted an approach that allowed to involve private forest owners from the entire state of Styria, Austria's most forest-rich state, boasting a forestation rate of 61.4 %. Due to the heterogeneous geography ranging from floodplains and wine regions at 200 m above sea level to high alpine areas up to 3,000 m, the forest composition is very diverse. This includes typical riparian forests in the south with poplar, willow, alder, and oak, to lower acid soil areas with beech-oak forests with fir and sweet chestnut in the east, to spruce, beech, pine, fir, ash, sycamore in the mid-altitudes, and up to larch and stone pine in the high mountains. 65 % of the forest is coniferous, 27 % is mixed forest, and 8 % is deciduous forest. 17.2 % of the forest area is a protection forest. Thanks to legally mandated reforestation and sustainable usage, the forest area is increasing, thus acting as an important CO₂ sink.

Styria is unique in Austria for its "dynamic forest typification," which allows even laypeople to select climate-adapted tree species, thereby enhancing stability as well as biodiversity. 22.9 % of Styria's forests are owned by large forest owners (more than 1000 ha), 55 % are owned by small forest owners (less than 200 ha), and ca. 9 % is owned by the Austrian Federal Forests Corporation. The forest is responsible for 1/6 of Styria's economic output. Styrian forests provide a range of important ecosystem services, including timber provision, CO₂ sequestration and habitat maintenance – three FES in focus. To facilitate transnational comparability and practical use of the assessment results the assessment was carried out in

three districts, where most applications to participate in the Living Lab came from, namely Bruck-Mürzzuschlag, Murau and Weiz.

3.2 France

The Grand Annecy Living Lab is located in the Haute-Savoie department of the Auvergne-Rhône-Alpes region and encompasses the city of Annecy and 33 surrounding municipalities, covering approximately 515 km² in the northern French Pre-Alps. Centred on Lake Annecy (27 km²), the territory forms a transitional zone between the Geneva basin and the alpine valleys, with elevations ranging from about 396 m in valley areas to more than 1,500 m on surrounding massifs. The geomorphology is shaped by Mesozoic limestone and marl formations, with Quaternary alluvial and glacial deposits in depressions and valley floors. Soils vary from alluvial and lacustrine substrates near the lake to shallow, calcareous soils on steep slopes. Groundwater levels fluctuate seasonally, from shallow aquifers in valleys to deeper karstic systems in the limestone mountains. The climate is montane, with a mean annual temperature of ~9.5 °C and annual precipitation of 1,600–1,650 mm.

Land use is structured around an urban core along the northern lakeshore, embedded within a broader matrix of agricultural zones and extensive forested landscapes. Forests cover roughly 23,000 ha, with ownership almost evenly split between public and communal forests managed by the National Forestry Office (ONF; 42 %) and private forests supported by the National Centre for Forest Ownership (CNPF; 58 %). Key forested massifs include Semnoz-Val Laudon, Tournette-Veyrier, and Parmelan-Glières.

Forest stands occur between 400 and 1,900 m and span three major vegetation belts. Deciduous species dominate lower elevations (oak, beech, chestnut, hornbeam), mixed and coniferous stands prevail in the montane zone (fir, spruce, beech), and spruce-dominated subalpine forests extend to higher altitudes. Deciduous forests represent approximately 65–70 % of forest cover, conifers 25–30 %. Stands are typically mixed-aged and two-layered, with natural forests comprising 70–80 % of the area. Average growing stock reaches 300–350 m³/ha, with an annual increment of 6–7 m³/ha and harvest rates below this threshold. Climate impacts, particularly drought-induced bark beetle outbreaks, have increased deadwood quantities and led to a decline in spruce monocultures. Current management emphasizes natural regeneration, species diversification, continuous cover, and selective harvesting adapted to slope conditions.

The region contains numerous protected and conservation areas, including national nature reserves (Roc de Chère, Bout du Lac), several Natura 2000 sites (totalling ~10,000 ha), 41 Sensitive Natural Areas (ENS), and 55 ZNIEFF sites. Forests also provide essential natural hazard mitigation functions by stabilizing steep slopes and protecting settlements from rockfalls and landslides. Grand Annecy is a major outdoor recreation destination, offering hiking, cycling, skiing, and water sports, supported by an extensive trail network (552 km) and ski areas such as Semnoz and Glières, alongside environmental education initiatives aimed at balancing recreation and conservation.

3.3 Germany

The German Living Lab is situated in Upper Bavaria, south of Munich, encompassing four administrative districts within a climatically diverse region spanning from Alpine Foothills to Northern Limestone Alps (591 m to 1328 m above sea level). It comprises 441.17 ha of forest, managed by two distinct entities: the Archdiocese Munich and Freising, and a private forest owner.

The heterogeneous topography and moist-continental climate leads to diverse forest compositions, from spruce-dominated stands to multi-layered mountainous mixed forests of spruce, beech, and fir, reflecting the area's natural communities. Ownership is split between the archdiocese, a large ecclesiastical

organization emphasizing ethical and sustainable management with economic, ecological, and social pillars, and a private owner who actively integrates sustainable timber production with social, ecological, and recreational functions, fostering community and cultural initiatives.

The Living Lab is committed to sustainable forest management, focusing on continuous timber production while providing crucial ecosystem services like carbon sequestration, habitat maintenance, and extensive recreational opportunities. A significant portion of the area is under various protection statuses, including Landscape Conservation Areas, Natura 2000 sites, and numerous biotopes, with a strong commitment to biodiversity through programs like the Contractual Nature Conservation Program "VNP Wald" and Climate-Adapted Forest Management "Klimaangepasstes Waldmanagement". A distinguishing feature is the considerable presence of protective forests, particularly in the private owner's area, safeguarding against natural hazards such as avalanches, slope fractures, and landslides, highlighting the critical role of forest in regional safety.

3.4 Italy

The Italian Living Lab is located in the south of the Piedmont region, bordering Liguria and France. It is identified as Forest Area 13, encompassing the Langa Cebana hills, Mongia, Cevetta, and Upper Tanaro valleys, with Alta Valle Tanaro being the largest in terms of surface. The LL covers 67,264 ha and includes 30 municipalities. Land use is characterized by extensive forest cover, primarily in mountainous areas, while hillside regions are predominantly dedicated to agriculture, featuring vineyards and hazelnut orchards. The area exhibits a Sublitoraneo rainfall pattern, with summer minimums and autumn maximums, alongside a secondary peak in spring. Solid precipitation is common between January and March, and snow cover typically persists for 3-4 months annually, with late snowfall being a frequent phenomenon. Elevations vary significantly, from sites along the Tanaro riverbed to peaks reaching 550 m a.s.l. in the north. The Tanaro Valley's complex geological structure, shaped by Alpine polyphasic deformation, results in diverse soil types, ranging from shallow and undeveloped in disturbed areas to deeper and well-developed soils. Forest covers 61% (41,358 ha) of the total LL area. Deciduous species overwhelmingly dominate, comprising approximately 88% of the forest cover, while conifers account for around 12%, largely due to mountain belt reforestation efforts. Key forest categories include Chestnut, Beech, and Downy Oak. Significantly, extensive chestnut stands, covering 18,812 ha, show a notable proportion of dead biomass (around 50%). More than 17% of the pilot area falls under various protected statuses, including Nature Conservation Areas, Banned Forests, Landscape Protection Areas, and several Natura 2000 sites, such as fractions of the ZSC/ZPS Alte Valli Pesio e Tanaro and natural parks like Parco del Maraguis. For natural hazard protection, 14% of the forest cover is managed as direct protection forest, predominantly beech coppice. While avalanches pose a less urgent risk, forest management plays a crucial role in mitigating frequent mudslides and floods. Recreation and tourism in the LL leverage the accessibility of its forests, the rich heritage of the valley and mountain chain, and its strong agronomic and culinary traditions. Hazelnut and chestnut orchards are iconic features that attract visitors, especially from Liguria and Piedmont. Major recreational activities include hiking and cycling, supported by 169.157 ml of regional cycling tracks, with a growing agrotourism sector. A unique educational asset is the Forestry School of Ormea, the only Italian public high school offering professional apprenticeships in forestry.

3.5 Slovenia

The Slovenian Living Lab (LL) is situated in the Municipality of Tržič, northern Slovenia, covering 15,500 ha. With a significant forest cover of 73 %, the area also features agricultural land in its lowlands and alpine pastures. Home to approximately 15,000 residents across 35 settlements, Tržič boasts a varied topography, ranging from the Karawanks mountain range, with peaks up to 2,133 m, down to river-glacial terraces at 424 m. The alpine climate is characterized by high annual precipitation, averaging 1,400 mm and exceeding 1,700 mm in higher elevations, and diverse geology resulting in a variety of soil types. Forest management for the LL's 11,290 ha of forest (72.7 % of the total area) is overseen by the Slovenian Forest Service (SFS), with local units and district foresters. Private forests constitute the majority at 85.5 %, fragmented among over 2,000 owners with an average property size of 0.5 ha, complemented by state (9.7 %) and municipal (4.7 %) ownership. The forest composition is predominantly Norway spruce (60 %) and European beech (21.4 %), with mixed forests accounting for 63.6% of the stands. The average growing stock is 401 m³/ha, with an annual increment of 7.87 m³/ha. Management adheres strictly to close-to-nature principles, prohibiting clear-cuts and emphasizing natural regeneration through irregular shelterwood and group selection systems, with rotation periods typically ranging from 120 to 160 years. Significant challenges include insufficient active management of protective forests (16.5 % of the total forest area), which impacts their stability and vitality, and the vulnerability of historical spruce monocultures to windthrow and bark beetle attacks. Beyond timber production, the LL provides crucial ecosystem services. Hunting is regulated by the SFS and is legally mandated for forest owners, reflecting a holistic ecosystem approach. Over 86 % of the forest area is designated as Natura 2000 sites, and the Dovžan Gorge is a prominent natural monument. The region is a popular destination for recreation and tourism, particularly for hikers, cyclists, and ski tourers, benefiting from its natural beauty, diverse attractions, and proximity to major cities like Ljubljana.

4. Forest ecosystem services in the Living Labs

This chapter gives an overview of the forest ecosystem services which have been assessed in the Living Labs from a biophysical and economic perspective. The chapter presents after an overview first the different forest ecosystem services, then the business models and finally draws some conclusions from a transnational perspective.

4.1 Introduction biophysical assessment

4.1.1 Overview assessed Forest Ecosystem Services

The table below provides a short overview of the forest ecosystem services which have been selected according to the local conditions and were assessed in all living labs. The ecosystem services are grouped according to the international classification system in provisioning, regulating and cultural services. In total eleven, six provisioning, three regulating and two cultural ecosystem services have been assessed.

Table 1: Presentation of a short overview of Forest Ecosystem Services in the Living Labs.

Forest Ecosystem Service	AUSTRIA	FRANCE	GERMANY	ITALY	SLOVENIA
Provisioning ecosystem services					
Provision of timber wood biomass	X	X	X	X	X
Provision of fire wood biomass	X	X	X	X	X
Provision of fuel wood biomass	X			X	
Provision of Non-Wood Forest Products (NWFP)				X	
Provision of forest spring water		X			
Provision of habitats for wild plants and animals	X	X	X	X	
Regulating ecosystem services					
CO2 storage and sequestration in forests / Climate Change Mitigation	X	X	X	X	
Natural Hazards (rockfalls, torrent) prevention/mitigation/control		X	X		X
Maintenance of high-quality fresh waters provided by plants and animal species		X	X		
Cultural ecosystem services					
Recreation and tourism		X	X	X	X
Aesthetic value of the forest		X		X	

4.1.2 Spatial levels of biophysical indicators

After the selection of the forest ecosystem services in each living lab, this set of FES was assessed and mapped based on local/regional as well based on large scale data and information. For each FES an indicator for the ecosystem service supply was identified for which existing data could be used. Data situation in the living labs differed, which required to choose appropriate indicators. Data were used at two levels:

- At a multi-territorial level, large scale data were used to capitalise on already existing databases from previous projects and to generate an alpine wide database to show the alpine dimension of these forest ecosystem services. Sources for such data are Copernicus data, reports of the European Environment Agency, Forest Europe, the European Forest Data Centre (EFDAC), the European Forest Institute (EFI), the Joint Research Centre (JRC), Eurostat or the European Environment Information and Observatio network (EIONET). Also information of previous Alpine Space projects can be used such as ALPES, RocktheAlps, AlpTree or Greenrisk4Alps.
- At local level, small scale data were used to check the accuracy of the large-scale data but also to demonstrate how private forest owners might apply an ecosystem service approach even with easy at hand data. Sources for these data are local or regional forest inventories, forest management plans and local knowledge of forest owners.

With these indicators the supply of FES was measured, which define the framework for maintenance, protection and improvement as well as possible alternatives.

In general it is feasible to merge local data in the presentation at a larger scale whereas the enlarging the measure of large scale data often is not satisfying as the resolution does not meet needs at a local scale. However, large scale data help to understand large scale developments and can be used at a strategic level to support political decision-making.

The source for large scale data, which need to be available across the entire Alpine area, are mainly existing datasets from Copernicus / European Space agency and expert level data from other Alpine Space projects. Large scale data have been modelled based on the remote sensing data and key information on dendrometric parameters from other forest projects. Then ecosystem service provision has been deducted and computed for each living lab area based on:

Total area, mean carbon storage, meand timber stock, mean annual growing stock (as high-, mid-, low-range), carbon sequestration (as high-, mid-, low-range) and differentiated for forest types (coniferous forest, deciduous forest, mixed forest).

For a detailed presentation of the methodology, the biophysical forest ecosystem service assessment and the potential effects of forest management on ecosystem services supply and the results for single living labs, are presented in the pilot action report, deliverable D2.2.1 Forest “Ecosystem services assessment”. Selected results are briefly summarized in the subchapters below.

In the next chapters the main results for biophysical assessments for the different forest ecosystem services in the five living lab areas are compiled. In this chapter the vive living lab areas of the project Forest EcoValue are introduced. The core data are presented in Table 2.

Table 2: Overview of the core data for the different living lab areas.

Pilot area	Grand Anancy, FR	Thonon agglomeration, FR	Alta Valle Tanaro, IT	Tegernsee Valley, DE	Graz, AT	Thannhausen, AT	Trzic, SI
Total forest area (ha)	26,209	9,696	43,3556	29,362	67,367	2,127	11,829
Annual growing stock increment across all forest types (m ² /ha/year)	5.11	3.73	7.22	11.67	10.05	9.43	8.16
Mean growing stock across all forest types (m ³ /ha)	352.28	343.05	425.79	543.16	417.67	456.32	447.58
Mean carbon stored (tC/ha)	115.90	112.86	140.08	178.70	137.41	150.13	147.25
Mean Carbon sequestration (TC/ha/year)	1.68	1.23	2.38	3.84	3.31	3.10	2.68
Pure Broadleaf (broadleaf species >= 70%) stand (expressed in % of the total forest area)	37.11 %	61.05 %	87.35 %	9.73 %	28.54 %	14.41 %	8.40 %
Mixed forest stand (expressed in % of the total forest area)	35.70 %	31.18 %	6.40 %	44.80 %	47.60 %	39.14 %	76.25 %
Pure coniferous (coniferous species >= 70%) stand (expressed in % of the total forest area)	27.19 %	7.78 %	6.25 %	45.47 %	23.86 %	46.45 %	15.35 %

4.2 Timberwood, firewood and fuel wood biomass

The ecosystem service of timber wood biomass has been assessed in the project on local and large-scale level. The traditional production output of forest is primarily determined by the provision of wood as a raw material. The wood obtained during felling can be categorised as stem wood, energy wood, industrial wood and non-utilisable wood. Sustainable timber production and utilisation ensures in general that the amount of timber harvested does not exceed the annual growth. This should ensure a constant supply of the raw material. However sustainable timber production is also a matter of scale. Small patterns of timber extraction will not harm the forest ecosystem whereas larger clear cuttings will have impacts on soil, microclimate, water retention and by this on the supply of forest ecosystem services.

Large Scale Assessment

Provision of wood biomass was computed as Mean Growing Stock (MGS) and as Annual Growing Stock (AGS) based on data which are available at the European Forest Carbon Monitoring project platform¹. The value of this indicator was calculated by averaging all growing stock data across each 20 × 20 m pixel classified as forest.

These data are proxies that can be used to quantitatively assess services related to timber production, energy wood production, and biomass production for biochemistry. However, the share of each of these product categories cannot be directly derived from the Mean Growing Stock alone. Such quantification requires site-specific knowledge of the proportion of the Mean Growing Stock that can be allocated to each of these three product categories

Timber wood biomass provision was modelled in the living labs of Austria, France, Germany, Italy and Slovenia. An example how the result looks like is given in Figure 2 for the French living lab Grand Annecy.

Table 3: Wood biomass provision across living labs

Wood biomass provision	Grand Annecy, FR	Thonon, FR	Tanaro Valley, IT	Endhausen / Waakirchen, DE	Thannhausen, AT	Trzic, SI
Area total (ha)	26,209	9,696	4,3356	31,425	2,127	11,829
Mean Growth (m ³ /ha/year): high-range estimate	6.53	4.76	7.27	15.86	11.56	16.96
Mean Growth (m ³ /ha/year): mid-range estimate	5.02	3.66	5.58	12.18	8.88	13.03
Mean Growth (m ³ /ha/year): low-range estimate	4.14	3.02	4.61	10.06	7.33	10.76
FES in % of the total forest area	100 %	100 %	100 %	100 %	100 %	100 %

The ecosystem service of wood biomass provision is provided in the total area of the living labs. A comparison of the living labs shows a significant high mean growth in Slovenia and Germany, whereas the living labs in France and Italy provide less wood biomass growth per hectare and year (s. Table 3).

¹ <https://www.forestcarbonplatform.org/>

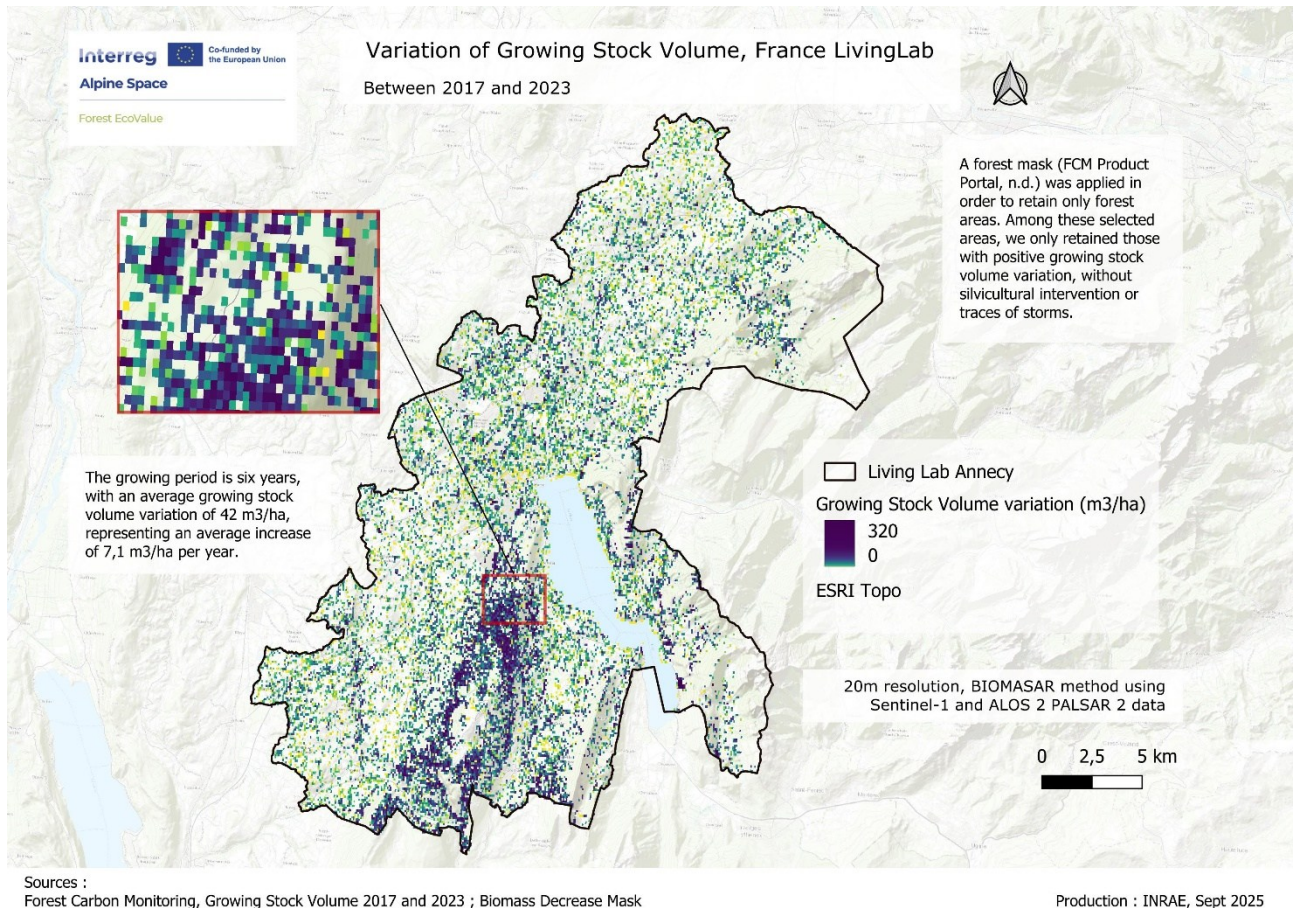


Figure 2: Growing stock volume increment in the French living lab part Anney (INRAE 2026)

Local Scale Assessment

The selected indicator for the local assessment is the absolute timber stock of derb wood without bark, measured in Efm D.o.R./ha (harvestable cubic metre diameter without bark per hectare). The harvestable cubic metre (Efm) refers to the usable volume of wood without bark and without gaps, corresponding to one stock cubic metre (Vfm) minus approximately 10% bark loss and 10% timber harvesting loss. This indicator was selected because it is widely accepted in the forestry and timber sector and accurately describes the available quantity of usable logs for sawmills and timber processing. Higher Efm/ha values indicate a greater supply of wood as a raw material.

Two different methodological approaches were applied for the local scale assessment, depending on different data availability. This allows to collect forest data for different data availability.

- For forest areas with detailed management data, such as those belonging to the Archdiocese Munich-Freising, the calculation was based on digital forest management data from 2016-2018, including information on tree species proportions, age distribution, utilisation type, stocking level, and harvesting stock in Efm D.o.R./ha, combined with increment and utilisation data from the 4th National Forest Inventory (2022) for Bavaria. The methodology involved determining average annual increment per tree species and average utilisation, converting increments to Efm/ha×a by deducting 20% harvest loss, calculating stock change between the last forest management period and 2024 for each tree species, adding this calculated change to the original harvesting stock, and finally adjusting for the actual stocking degree of each stand area. This approach provided stand-level spatial resolution based on forest management units.

- For forest areas with limited data availability, such as the private forest near Waakirchen, a different approach was applied. The available data included a digital terrain model (1.0m resolution), digital surface model (0.8m resolution), High Resolution Layer Forest Types from Copernicus (10m resolution), and a digitised analogue forest management map from 2016 showing age classes and stand boundaries. The methodology involved digitising the analogue management map and creating stand numbers, calculating a normalised digital surface model (nDSM) from the difference between the surface and terrain models, extracting vegetation heights and performing statistical analysis per stand (using the 3rd quantile as "upper stand height"), estimating timber stock using auxiliary forestry yield tables (Assmann & Franz 1963) based on top-height bonus curves, stand age, and tree height, and interpolating values for intermediate estimates between known measured values. This approach also provided stand-level spatial resolution based on management compartments.

For further information on the methodology and data sources for the local scale indicator an indicator factsheet is provided in the annex.

4.3 Provision of habitats for wild plants and animals

Large Scale Assessment

The large-scale assessment builds on three criteria which were applied to the total forest area:

- Forest area under protection management such as Natura 2000 sites or biotope protection orders. The boundaries of these areas are available through the Natura 2000 website.
- Area of riparian forests. Riparian forests were identified by applying a 20 m buffer on both sides of the axis of hydraulic features (rivers and torrents) within the forest area.
- Area of riparian forests under protection scheme within the forest area

Table 4: Provision of habitats for wild plants and animals

Habitat provision for wild plants and animals	Grand Annecy, FR	Thonon, FR	Tanaro Valley, IT	Endl-hausen / Waa-kirchen, DE	Thann-hausen, AT	Trzic, SI
Area total (ha)	1,299	1,333	43,356	4015,62	205	10,414
FES in % of the total forest area	4.96 %	13.75 %	100 %	12.78 %	9.64 %	88.04 %

The shares of forest area with habitat provision in the different living labs differ significantly between the types of living labs (s. Table 4). Italy and Slovenia offer the highest share of forests which offer habitats for wild plants and animals, whereas German, Austrian and French living labs have comparably low shares, particularly the habitat provision in Grand Annecy, which is close to the urban area of Annecy, is low. As an example for the spatial distribution of this ecosystem service the habitat provision in the German living lab area is presented in Figure 3.

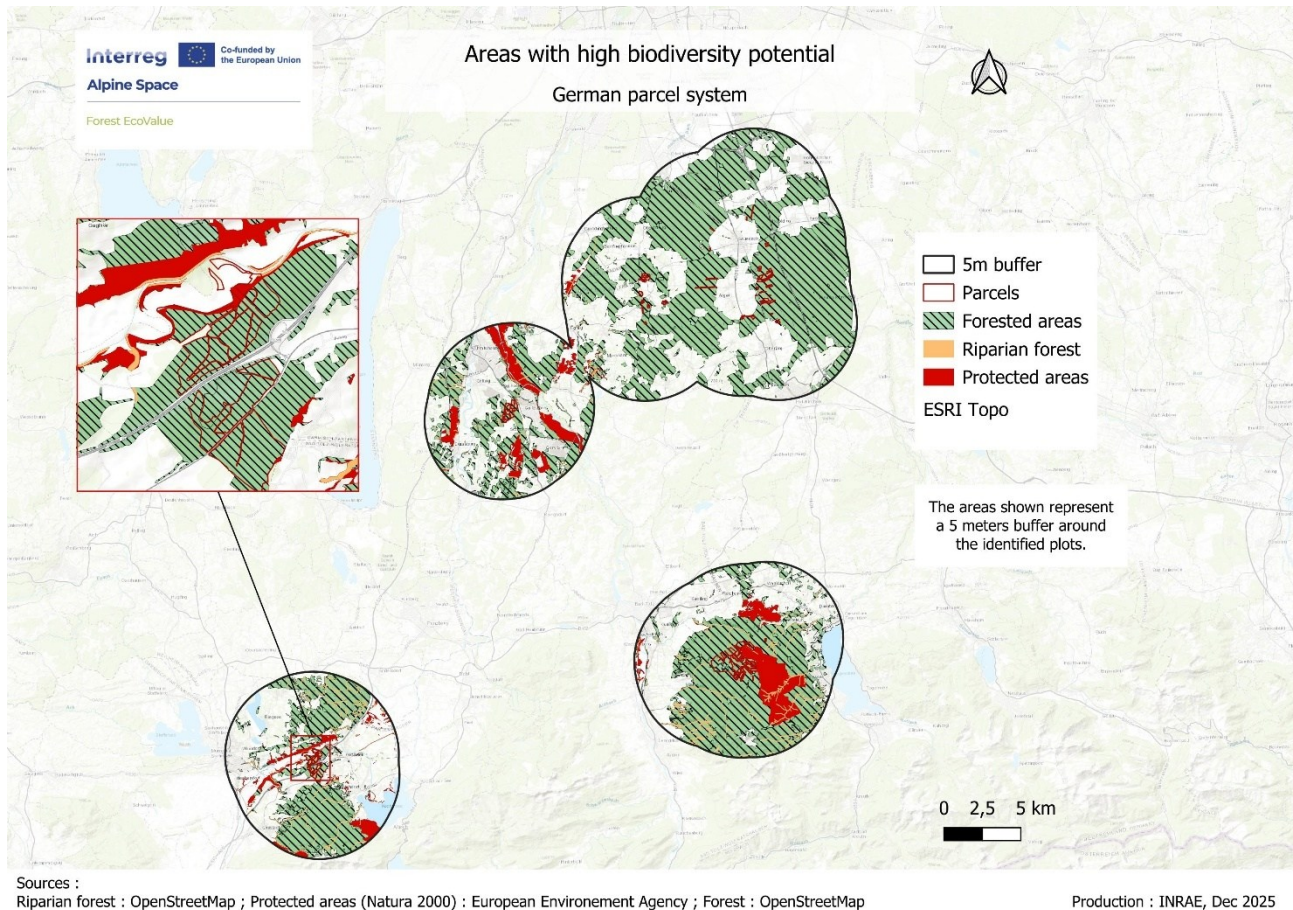


Figure 3: Habitat provision in the German living lab Endlhausen and Waakirchen.

Local Scale Assessment

This FES was assessed at local scale in the German Living Lab using the "Species and Habitats" protected asset map from the Bavarian State Office for the Environment (LfU 2025). The selected indicator is a habitat quality index that assesses current habitat function regarding the occurrence of plant and animal species. Values range from 1 (predominantly very low quality) to 5 (predominantly very high quality), combining legal protection status, hemeroby (utilization type and location), and biotope density. This indicator was selected because it represents a comprehensive, freely available data basis applicable throughout Bavaria, bringing together multiple assessment criteria including protected area classifications, species conservation mapping, and mapped biotopes.

The assessment follows a hierarchically graded decision cascade. Value level 5 includes areas with legal protection status such as nature conservation areas and Natura 2000 sites. Value level 4 comprises areas verified by specialized mapping, including species conservation mapping from 1990 onwards and areas with high biotope density. Value levels 3 to 1 represent interpretations based on hemeroby criteria and utilization types. The information from the protected assets map was transferred to the study areas using GIS tools. The spatial resolution corresponds to the target scale of 1:25,000 to 1:100,000. It should be noted that all value levels are labelled with "predominantly" due to the scale and data quality. High-quality habitats may occur in lower value categories that could not be recorded with available data, particularly in grassland-dominated landscapes and forests where biotope mapping may be inadequate. Figure 4 shows the habitat provision in the German living lab on local scale.

Large Scale Assessment

For the large scale assessment as indicator the Mean Growing stock was used as input data and an average correction factor of 0.37. For the indicator of maximum annual carbon sequestration, the calculation principle is the same, with the Annual Growing Stock Increment used as the input data.

Table 5: Carbon sequestration

Carbon sequestration	Grand Anancy, FR	Thonon, FR	Tanaro Valley, IT	Endlhause n / Waa-kirchen, DE	Thann-hausen, AT	Trzic, SI
Area total (ha)	26,209	9,696	43,356	31,425	2,127	11,829
mean Carbon stored (T/ha)	116.53	136.03	101.78	210.31	169.44	136.96
Carbon sequestration (T/ha/year): high-range estimate	3.10	2.26	3.45	7.53	5.49	8.06
Carbon sequestration (T/year): mid-range estimate	2.38	1.74	2.65	5.79	4.22	6.19
Carbon sequestration (T/ha/year): low-range estimate	1.97	1.44	2.19	4.78	3.48	5.11
FES in % of the total forest area	100 %	100 %	100 %	100 %	100 %	100 %

The table reflects what was already visible for the growth rates: the higher productivity of forests in Slovenia and Germany delivers a higher carbon sequestration, carbon sequestration in the Italian and French area is lower. In Figure 5 as an example the carbon sequestration for the mid-range estimate in the Slovenian Living lab is presented.

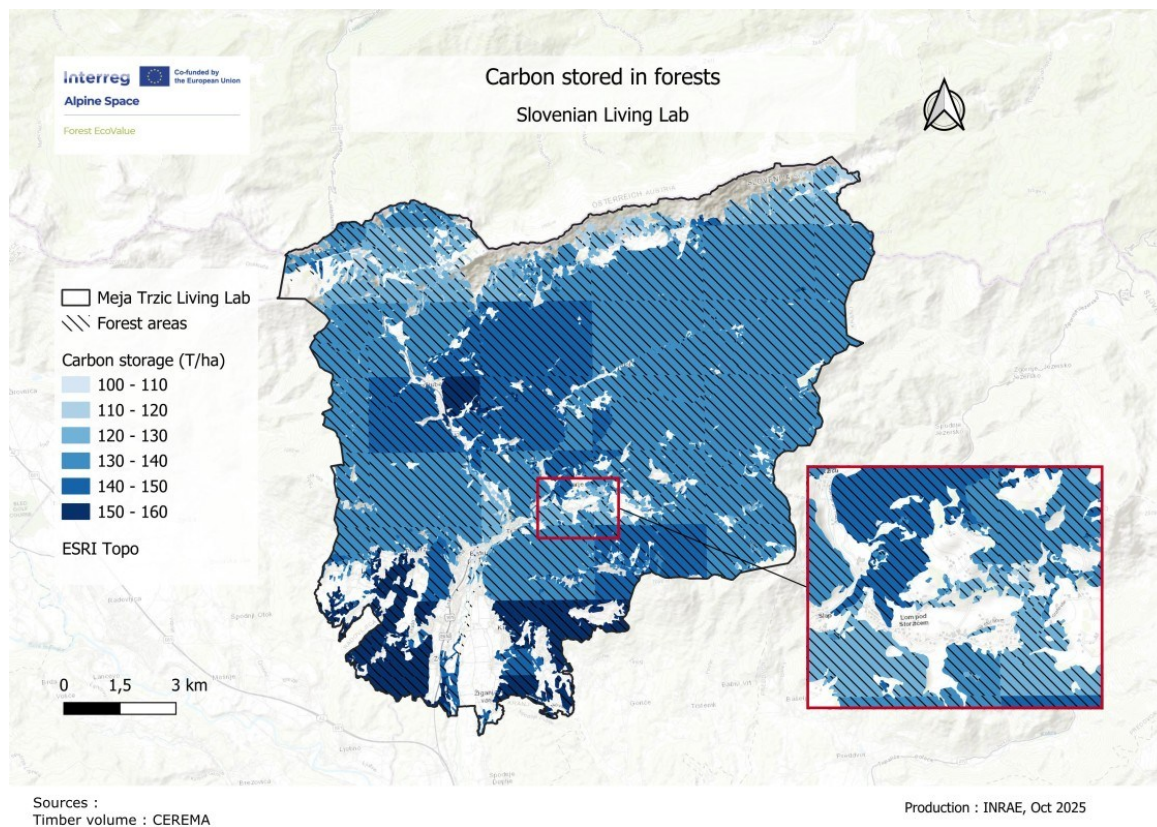


Figure 5: Carbon storage in the Slovenian living lab.

For further information on the methodology and data sources for the local scale indicator an indicator factsheet is provided in the annex. This includes including references to Klein & Schulz (2012) and a documentation of the calculation steps.

4.5 Natural hazard prevention, mitigation and control

A large number of natural hazards can pose a risk to human health and infrastructure. Forest ecosystems can mitigate the effects and ensure that rockfalls are intercepted and the triggering of avalanches is prevented. In addition, tree roots ensure greater stability of the terrain, which can prevent slope failures. Forests slow down and protect against shallow landslides and avalanches and can absorb rockfalls. The ecosystem service of natural hazard prevention, mitigation and control has been assessed on local and large-scale level.

Large Scale Assessment

Natural hazards by rockfall was indicated by a model developed in the Interreg Alpine Space project ROCK the ALPS. Based on a digital terrain model with a 25 × 25 m resolution. potential release areas were defined using two slope thresholds:

- a high probability for slopes greater than or equal to 42°, and
- a lower but non-zero probability for slopes in the range of 28° to less than 42°.

For the release areas a propagation model was applied to define the maximum propagation zones without forest cover. The propagation zones were compared with exposed infrastructure (railways, buildings, and main roads) based on Open Street Map data. The protection effect of forests was calculated by the intersection of propagation zones, the protected assets and the forest areas. For the extent the protection service is provided two proxy indicators were calculated: (i) the forest area capable of providing a protective service across all asset types, and (ii) the length of roads protected. For each living lab, results are expressed as a percentage of the total forest area providing the forest ecosystem service.

Table 6: Regulating service Natural hazard prevention against rockfall

Natural hazard prevention against rockfall	Grand Anancy, FR	Thonon, FR	Tanaro Valley, IT	Endhausen / Waa-kirchen, DE	Thannhausen, AT	Trzic, SI
Area total (ha)	8,678	0	6,796	0	76	1,180
FES in % of the total forest area	33.11 %	0 %	15.68 %	0 %	3.59 %	9.98 %

The share of forest area, which provides prevention against rockfall is the highest in the French living lab part Anancy and it is not existent in the living lab part Thonon and the German living lab. High shares also exist in the Tanaro valley, Italy and the Slovenian living lab. This may be also partly influenced by the topography, in steep valley shoulders rockfall prevention is more relevant than in soft valleys.

The provision of this regulation service is presented in Figure 7 as an example for the Italian living lab.

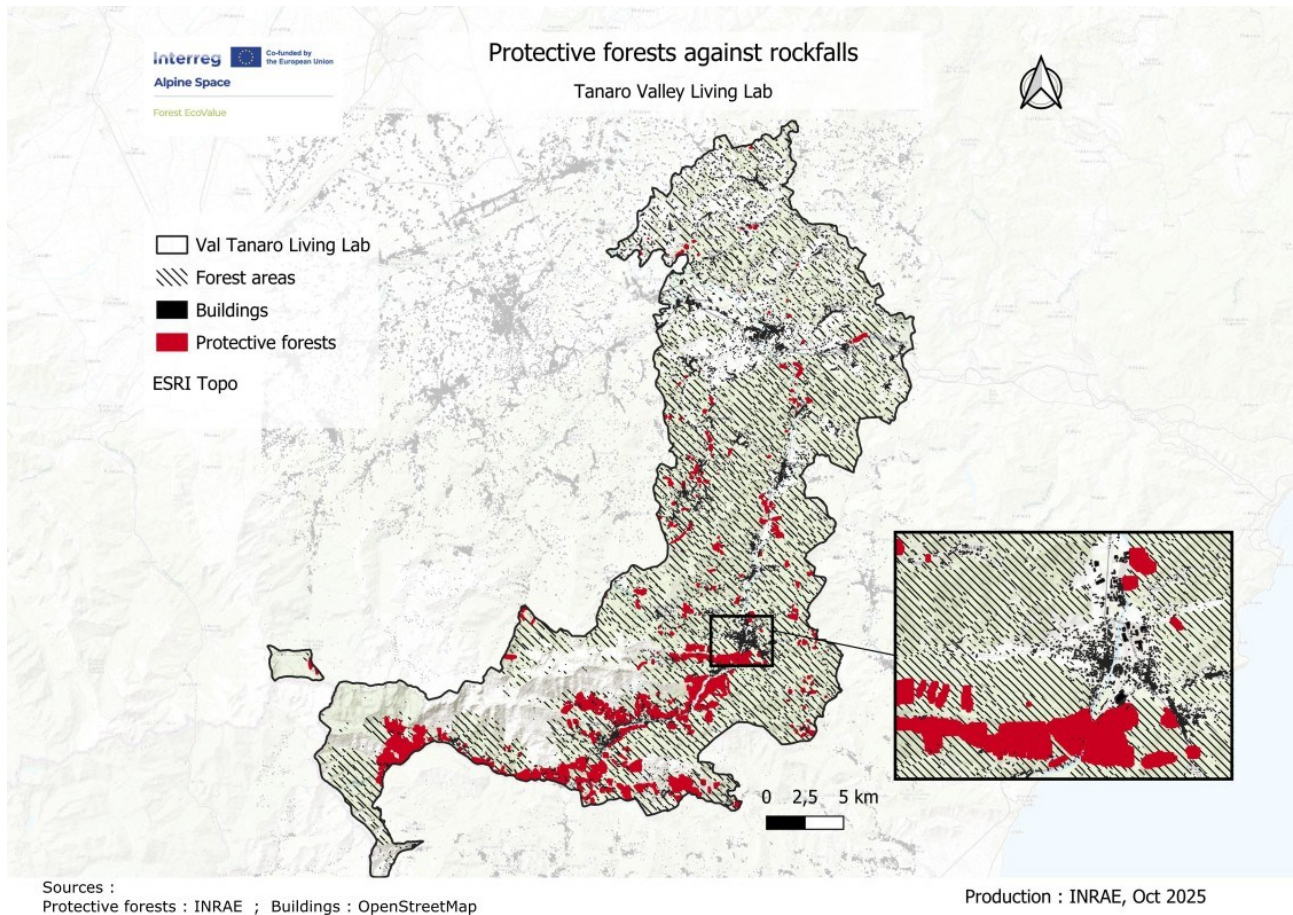


Figure 7: Rockfall prevention in the Italian living lab.

Torrent-related hazards were only considered in the Slovenian living lab. An approach similar to that used for rockfall hazards was applied. A specific model was developed to identify forest areas protecting riverbanks and torrent banks using two non-planimetric buffers (20 m and 40 m), as well as zones of propagation for debris flows, torrential floods, and debris torrents originating from catchment headwaters, sources of hydraulic features, and connection points between hydraulic features.

As the model was calibrated using an observed event database, it makes it possible to identify both threatened assets and forest areas that regulate these hazards. At the scale of the Slovenian site, results are expressed as a percentage of the total forest area.

Local Scale Assessment

This FES was assessed at local scale in the German Living Lab using detailed indicator-based mapping combining multiple data sources (s. Figure 8). The selected indicator is the percentage of forest classified as protective forest or functional forest per survey area, combined with natural hazard potential mapping from the Bavarian hazard information map. This indicator combines official forest designations (protective forest according to Art. 10 BayWaldG, functional forest according to Art. 6 BayWaldG) with modelled hazard zones. The proportion of forest can be easily determined and has been found highly significant for natural hazard probability. Forests provide protection primarily against rockfall, slope failures, landslides, and avalanches.

4.6 Maintenance of high-quality freshwater

The ecosystem service of high-quality fresh waters has been assessed on local and large-scale level.

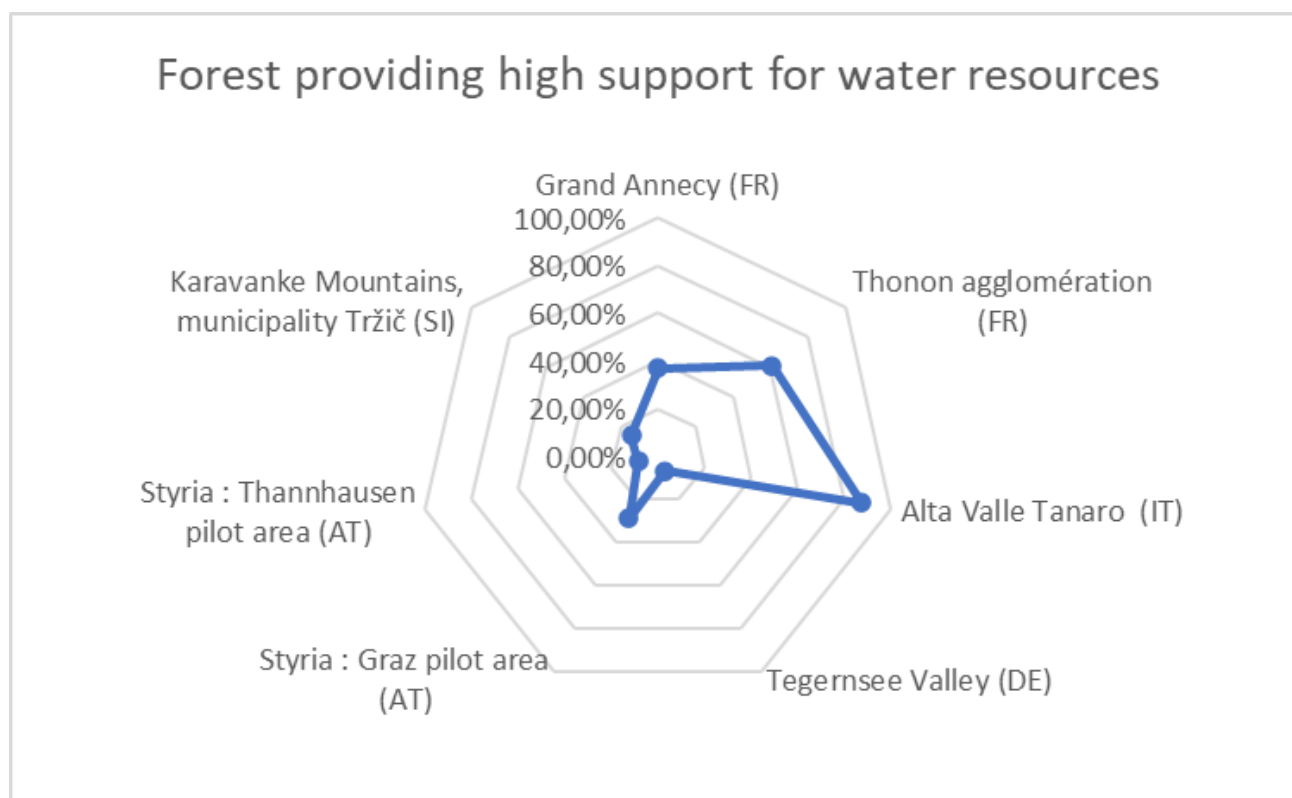
Large Scale Assessment

For the assessment of provision and maintenance of high-quality freshwater the main forest stand type categories were used as input data with the classification scheme in Table 7.

Table 7: Classification scheme for high-quality freshwater provision

Support of ecosystem service	Main forest stand
Very high support	Pure broadleaved forests (broadleaf species > 70 %)
High support	Mixed forests
Moderate to low support	Pure coniferous forests (coniferous species > 70 %)

The results of this proxy indicator are expressed, for each site, as the percentage of the forest area concerned relative to the total forest area. The three graphs below represent low, medium and high support shares of forests for the provision of high-quality freshwater.



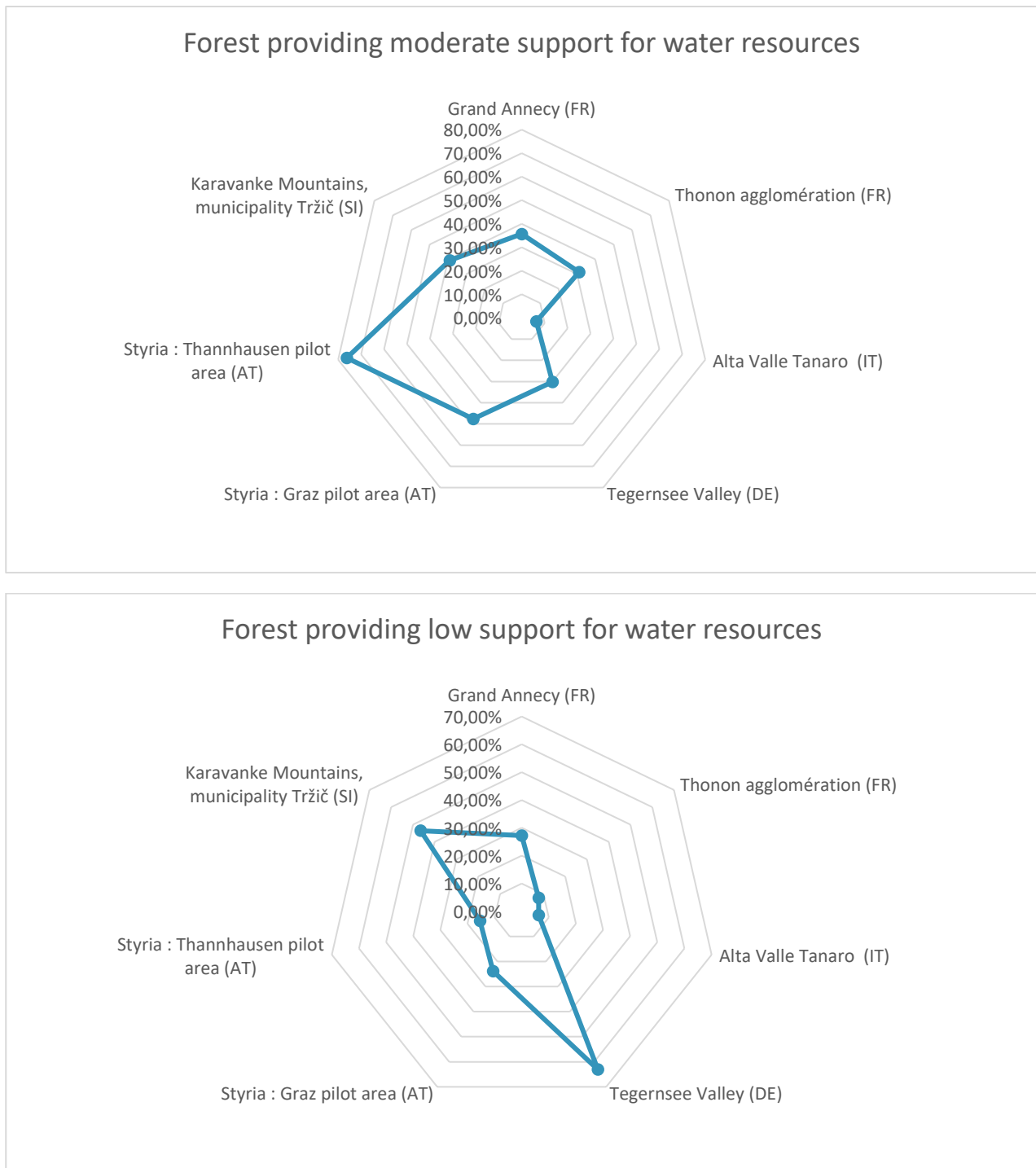


Figure 9: Graphs representing low, medium and high support shares of forests for the provision of high-quality freshwater.

Local Scale Assessment

This FES was assessed at local scale in the German Living Lab using detailed indicator-based mapping. The selected indicator is a forest structure index combining proportion of hardwood and forest cover. This five-level index (0-5) is based on the percentage of deciduous trees per stand, with an additional level 0 for bare or unstocked areas. Higher values indicate better drinking water provision potential. The indicator captures the two most important stand parameters for drinking water quality: permanent forest cover, which contributes to nutrient uptake and maintains soil structure while clear-cutting impairs these

functions; and proportion of hardwoods, where higher deciduous tree content improves water quality by reducing nitrate leaching. The indicator is both practical for data collection and scientifically relevant.

The methodology determines mixture ratios from forest management data or, where missing, from Copernicus High Resolution Layer Forest Types with values calculated proportionally to stand size. Forest cover is assessed by calculating a normalized digital surface model from the difference between surface and terrain models, then identifying in the GIS bare areas where height values are 0-1 m over minimum contiguous areas of 1,000 m² with minimum width of 30 m. The forest structure indicator is then classified on a scale from 0 (bare surface) to 5 (forest with 81-100% deciduous trees), with intermediate levels representing forests with 0-20%, 21-40%, 41-60%, and 61-80% deciduous trees respectively, see **Table 8**. Areas without designated forest use such as forest meadows, paths, and agricultural areas are excluded. The spatial resolution is at stand level or 1 m grid for bare area detection. The scientific background is based on nitrogen (nitrate) as a key parameter for drinking water quality, where values below 2.5 mg/l are harmless while values above 10 mg/l are critical. Permanent forest cover with high deciduous proportions minimizes nitrate concentrations through continuous nutrient uptake and stable soil structure.

Table 8 Forest structure indicator classification

Level	Forest cover	% Deciduous trees per stand
0	Bare surface	-
1	Forest	0-20 %
2	Forest	21-40 %
3	Forest	41-60 %
4	Forest	61-80 %
5	Forest	81-100 %

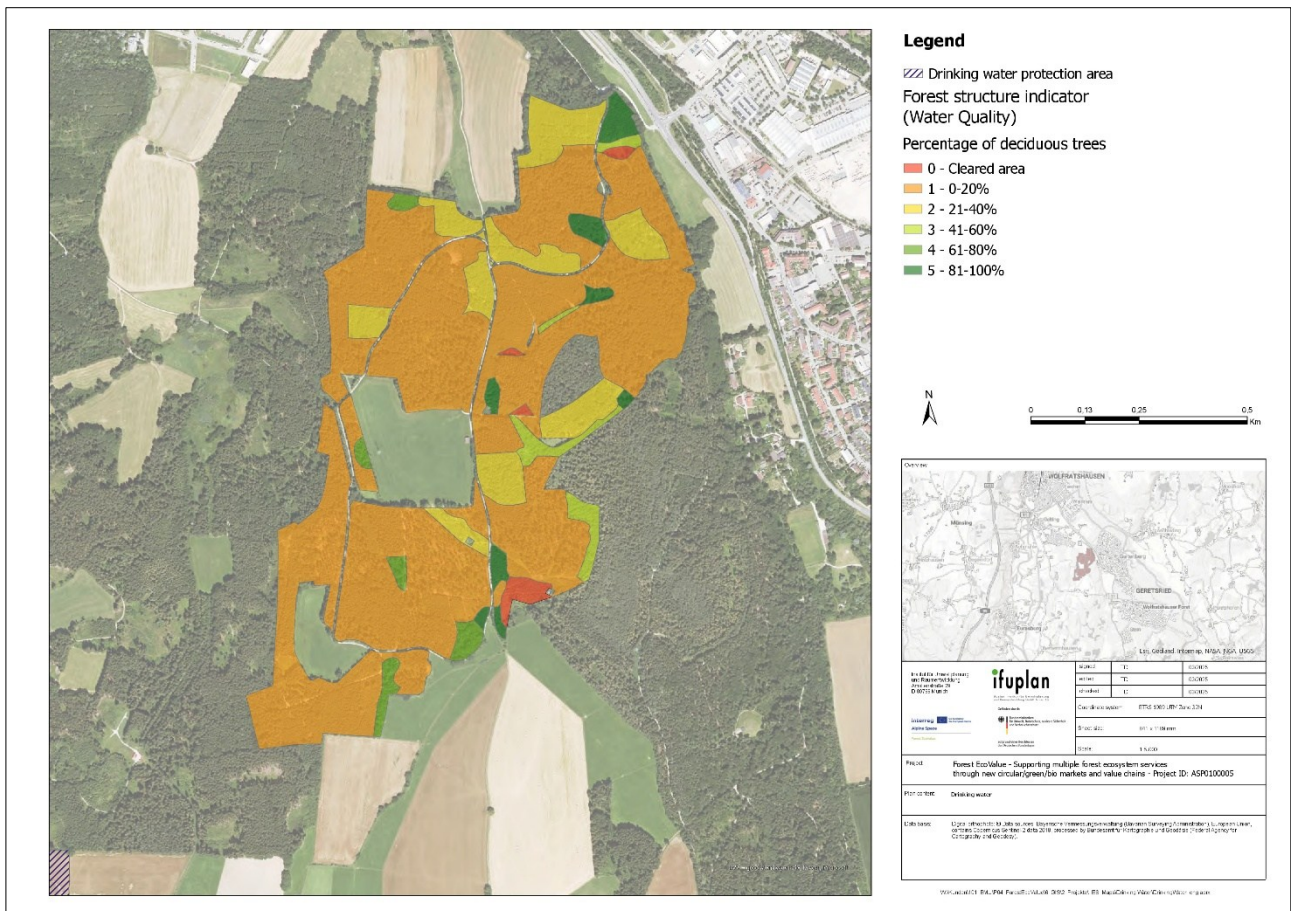


Figure 10: Water provision potential in the German Living Lab.

For further information on the methodology and data sources for the local scale indicator an indicator factsheet is provided in the annex.

4.7 Recreation

The forest ecosystem service recreation refers to the intangible benefits that people derive for their well-being and health from spending time in forest ecosystems. This cultural service includes opportunities for stress reduction, mental and physical regeneration as well as active and passive leisure activities in a natural environment.

The ecosystem service recreation has been assessed on local and large-scale level.

Large Scale Assessment

The assessment using large scale data is based on two criteria for recreation services: the accessibility of forest areas and the viewpoints from or towards the forest.

- The accessibility was identified as the area that is accessible or visible within a 50 m buffer on each side of all access routes to forest areas (roads, tracks, and paths) within the forested area. Only the portion of this buffer located within forested areas was considered.
- The viewpoint analysis was carried out for each forest polygon. Each forest polygon was assigned the total number of viewpoints from which it is visible, and the calculation was performed only for polygons visible from at least one viewpoint.

Finally, the forest areas were identified using these two criteria in the way the forest areas were intersected in order to retain areas where either one of the two criteria is present or where both are present. The final proxy indicator was obtained by overlaying the maps corresponding to these two criteria and calculating the total area associated with the presence of only one criterion and of both criteria.

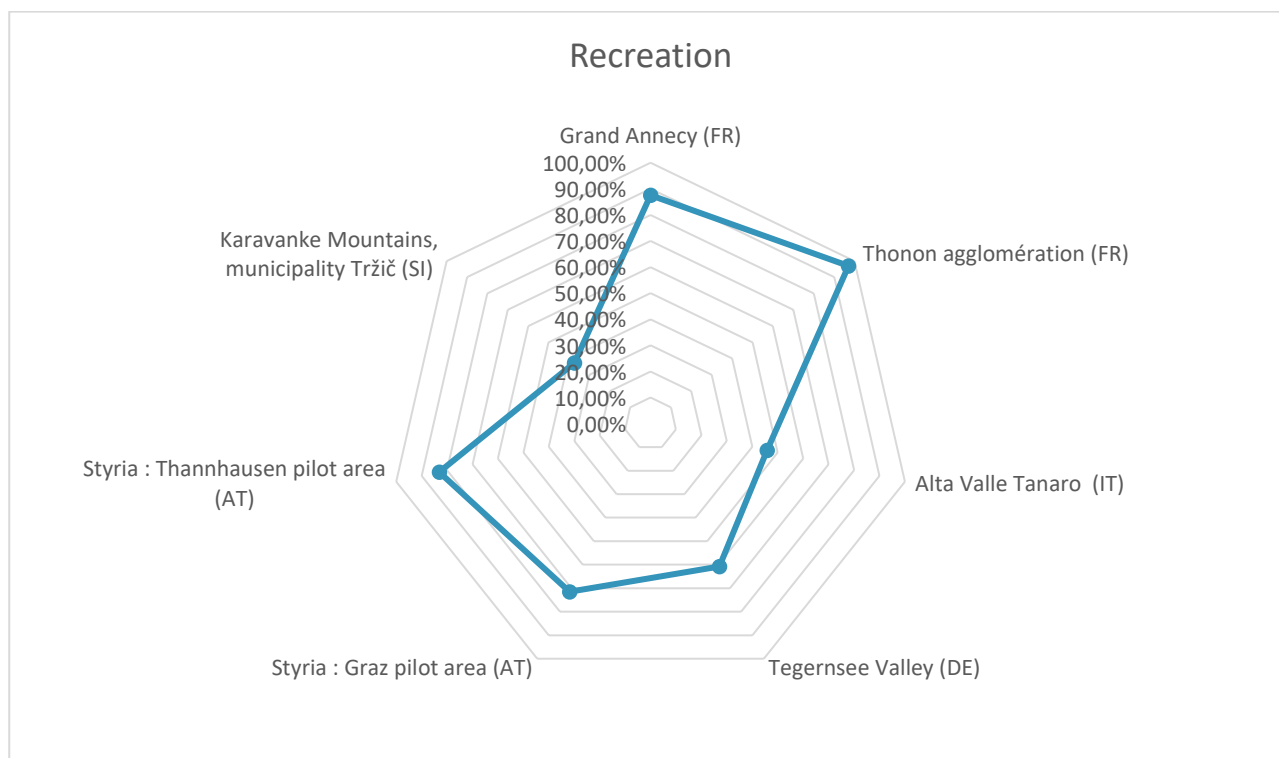


Figure 11: Percentage of forest areas providing recreational services comparing the living lab areas

The forest area providing the cultural ecosystem services recreation was identified by this approach and the share of forest areas in the living lab areas is presented in Table 9.

Table 9: Cultural service recreation in living lab areas.

Recreation	Grand Annecy, FR	Thonon, FR	Tanaro Valley, IT	Endl-hausen / Waa-kirchen, DE	Thann-hausen, AT	Trzic, SI
Area total (ha)	22,945	9,410	19,879	19,092	1,768	4,414
FES in % of the total forest area	87.55 %	97.04 %	45.85 %	60.75 %	83.13 %	37.32 %

In general, the share of forest areas providing recreation services is relatively high in France and Austria (above 80 %) of the forest area, also in Germany at least 60 % of the forest area are relevant for recreation. The share of forest areas providing recreation services in Austria and Slovenia is around 40 %.

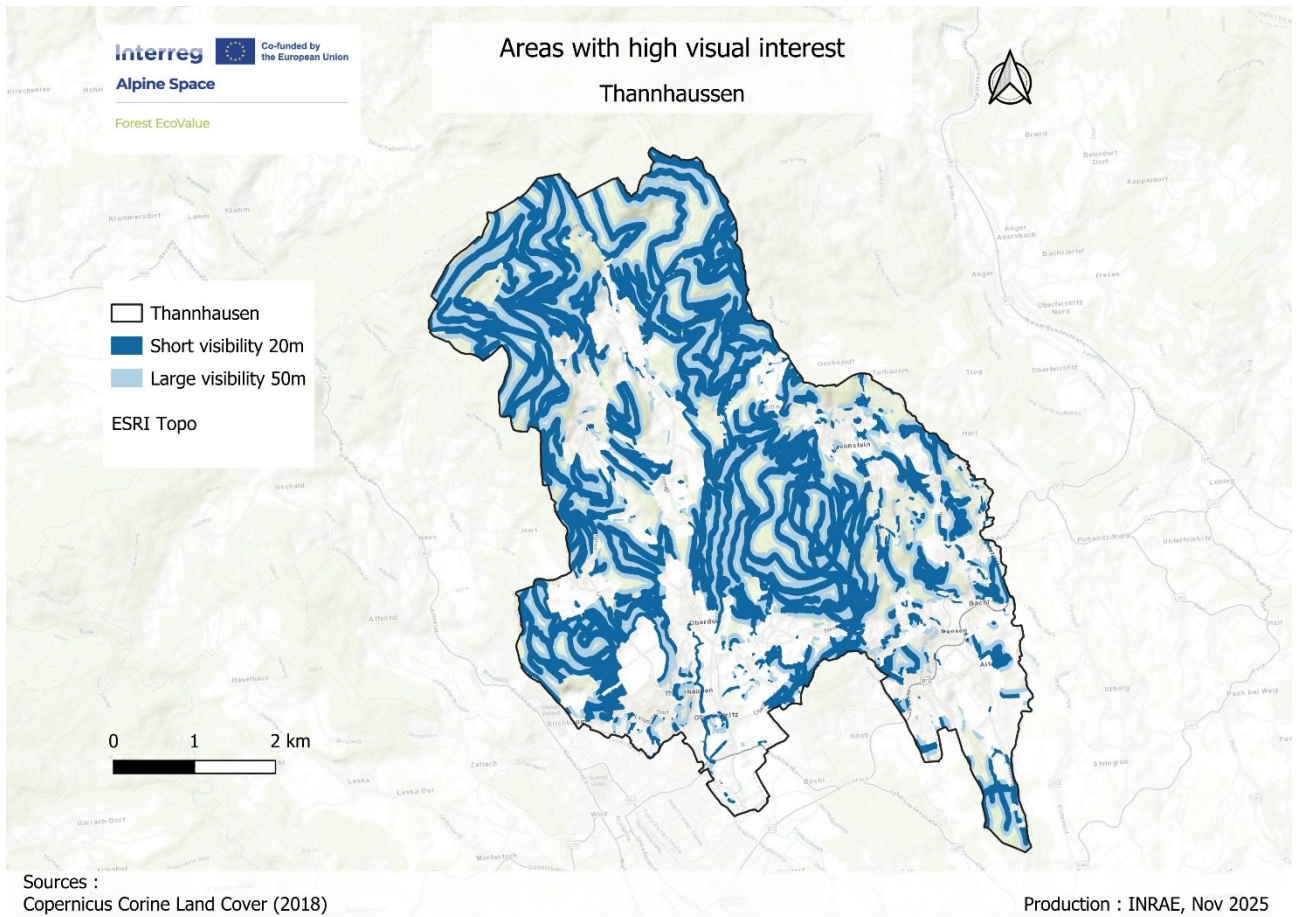


Figure 12: Cultural service recreation – example Austrian living lab Thannhausen.

Local Scale Assessment

This FES was assessed at local scale in the German Living Lab using detailed indicator-based mapping. The selected indicator is potential recreational value, a composite index ranging from 1 to 9 where higher values indicate greater recreational potential. The index combines three factors: proximity to trail network (within or outside 40m buffer), age of forest stands (clear areas, young stands, old stands), and mixture ratio (pure versus mixed stands with deciduous and coniferous species). This indicator was selected based on empirical research (Edwards et al. 2010) showing that recreational value is significantly influenced by forest accessibility, stand structure, and species diversity. Mixed old-growth forests near paths offer optimal conditions for recreation.

The methodology utilizes path network data from OpenStreetMap, extracting relevant categories such as tracks, paths, and footways while excluding major roads. A 40m buffer zone is created around paths to classify forest accessibility. Stand age is classified from forest management data, with young stands including young stand management and young thinning types, and old stands including old thinning, regeneration utilization, and long-term treatment types. Clear areas are identified either through utilization type data or by analyzing normalized digital surface models where heights between 0-1.5m over minimum areas of 1,000m² indicate unstocked land. Mixture ratios are determined from forest management data or, where missing, from Copernicus data, with mixed stands defined as having more than 10% each of deciduous and coniferous wood following German National Forest Inventory definitions. The potential recreational value is then calculated on a scale from 1 (clear areas) to 9 (within 40m of path, old stand, mixed composition), providing stand-level spatial resolution, see Table 10.

Table 10: Recreational values for the classification of recreation services.

Recreational Value	Path Network	Age	Mixture
1	-	Clear area	-
2	Outside 40m	Young	Pure stand
3	Outside 40m	Young	Mixed stand
4	Outside 40m	Old	Pure stand
5	Outside 40m	Old	Mixed stand
6	Within 40m	Young	Pure stand
7	Within 40m	Young	Mixed stand
8	Within 40m	Old	Pure stand
9	Within 40m	Old	Mixed stand

5 Economic assessments in the living labs

In each LL the social value of the selected subset of FES was assessed by using the unit value transfer method which was supplemented with a direct market valuation for provisioning and carbon storage ecosystem services.

The method of the value transfer estimates an approximate value for the FES in the respective living lab. The values used are based on existing valuation studies which have been compiled and analysed in a previous step of the project (cf. D1.2.3). This method delivers economic values of low precision, but it can be homogeneously applied to all pilot areas in the living labs and to address different ecosystem services simultaneously and identify potential trade-offs.

For each country a unique unit value for this FES and country was determined if several values were available. If no primary valuation studies were available, such in the case of France, values were used from local reports or unpublished results of other Interreg projects. Also unit values have been adjusted to the local socio-economic context by conversion factors for each project partner country.

For further, detailed information please check D2.3.1 Transnational Pilot Testing of FES Economic Assessment and Market Frameworks in LLs.

5.1 Timber wood biomass

Indicators and data used for the economic assessment

Main indicators which were used to assess the economic value of the ecosystem service timber wood biomass are the total forest area and the logging potential.

- Logging potential
 - Austria: Logging potential in solid cubic meter, before losses due to processing, estimated based on the actual logging data reported for the Weiz District in solid cubic meter, before losses due to processing (Efm in German) and yearly increment reported solid cubic meters without bark (Vfm in German)
 - Germany: Logging potential in solid cubic meter, before losses due to processing, estimated based on the actual logging data reported for Bavaria in solid cubic meter, before losses due to processing (Efm in German) and yearly increment reported solid cubic meters without bark (Vfm in German)
 - France: Logging potential in m³, estimated from the territorial forest plan
 - Slovenia: Logging potential in m³, estimated based on the average annual logging rate in the LL (5 m³/ha) and the total forest area
- Total forest area in ha
- Direct market value (DMV) in €/ha/yr (in 2023)
- Adjusted unit value (AUV) in €/ha/yr (in 2023)
- Total economic values derived using DMV and AUV valuation methods

Main results

The results of the economic assessment for timber wood biomass of the different living labs are compiled in the table below.

Table 11: Main results for economic valuation of timber wood biomass

Indicators and Data used	Unit	Grand Anancy, FR	Thonon, FR	Tanaro Valley, IT	Endl-hausen, DE	Waa-kirchen, DE	Thann-hausen, AT	Tržic, SI
Total forest area	ha	26,209	9,696	43,356	23361	8,060	2,127	11,829
Logging potential	DE, AT: solid cubic meter IT, SI: m ³	-	-	381,461	113,816	39,269	10,368	5,006
Direct market value (DMV)	€/ha/yr	-	-	175.45	461.92	461.92	314.61	393.72
Total economic value, DMV	€/yr	-	-	7,606,789	10,791,096	3,723,131	669,070	4,657,381
Adjusted unit value (AUV)	€/ha/yr	174.46	174.46	152.06	168.69	168.69	173.74	139.19
Total economic value (TEV)	€/yr	4,572,510	1,691,645	6,592,582	3,940,782	1,359,644	369,480	1,646,488

5.1.1 Conclusions for all living labs

Based on the assessed values for timber wood biomass these conclusions are valid for all LLs:

- Overlap with other ecosystem services:** The forest areas producing timber also provide carbon sequestration and other regulating and cultural services, meaning that intensified timber extraction could lead to trade-offs and potentially reduce overall social value. Balanced, multifunctional management is therefore essential, as a mono-functional focus could reduce total forest social value. Sustained policy support of and financial mechanisms for existing multifunctional management are therefore essential.
- Contribution to forest total economic value:** Timber wood provision constitutes a moderate share of the forest's TEV in the living labs. While economically relevant, its contribution is clearly lower than that of regulating and cultural services such as recreation, rockfall protection, and carbon sequestration. This suggests less reliance on timber production and greater societal emphasis on non-provisioning services.
- Monetary valuation sensitivity:** The method used strongly affects the valuation outcome. The market price (MP) approach raises the social relevance of this FES above cultural services, suggesting that average Alpine value (i.e., adjusted unit value) significantly underestimates the social value of timber provision. At the same time, adjusted unit values of other FES could also be underestimated, which necessitates great caution in comparative analysis.

5.1.2 *Specific conclusions for single living labs*

Based on the assessed values for timber wood biomass specific conclusions for single LLs are:

Austria: Thannhausen

- High relevance within FES portfolio, but moderate contribution to forest TEV: Timber wood provision ranks among the top five most valuable FES in Thannhausen, contributing about 30 % of the total economic value (TEV) of the forest ecosystem.

France: Thonon

- Timber wood provision has a lower relative unit value than major regulating services, particularly natural hazard mitigation and habitat provision. It is also outperformed by carbon sequestration when the latter is valued using upper-bound carbon pricing, indicating that broader societal priorities place more emphasis on regulating services than on timber biomass production.

Germany

- Since the logging data used for the estimates was derived from the data reported for Bavaria, unit values calculated using DMV are the same for both Living Labs.
- High relevance within FES portfolio, but moderate contribution to forest TEV: Timber biomass provision ranks among the top five most valuable FES in the German living labs, but accounts for about 30% of the TEV (Endlhausen) respectively just under 30 % of the TEV (Waakrichen), which is however comparable with the contributions of other relevant FES such as recreation and carbon sequestration in the conservative TEV, with carbon sequestration exceeding the contribution by almost 20 % in an upper-bound TEV.

Italy

- Moderate relevance within FES portfolio: Timber wood provision ranks among the top five most valuable FES, contributing however around 20 % of the total economic value (TEV) of the forest ecosystem, reflecting the broader social importance of forest beyond timber production.
- Low monetary valuation sensitivity: Both market price valuation and value transfer generate similar unit value per ha, only slightly overestimated by value transfer. This suggests that adjusted unit value transfer method provides an estimate aligned with local context.

Slovenia

- Moderate relevance within FES portfolio: Timber wood provision ranks among the top five most valuable FES, however, contributing between 15 and 23 % of the total economic value (TEV) of the forest ecosystem, depending on the valuation method used.

5.2 Firewood biomass

Indicators and data used for the economic assessment

Main indicators which were used to assess the economic value of the ecosystem service firewood biomass are the total forest area and the logging potential.

- Logging potential
 - Austria: Logging potential in solid cubic meter, before losses due to processing, estimated based on the actual logging data reported for the Weiz District in solid cubic meter, before losses due to processing (Efm in German) and yearly increment reported solid cubic meters without bark (Vfm in German)
 - Germany: Logging potential in solid cubic meter, before losses due to processing, estimated based on the actual logging data reported for Bavaria in solid cubic meter, before losses due to processing (Efm in German) and yearly increment reported solid cubic meters without bark (Vfm in German)
 - Italy: Logging potential in m³, estimated from the territorial forest plan
 - Slovenia: Logging potential in m³, estimated based on the average annual logging rate in the LL (5 m³/ha) and the total forest area
- Total forest area in ha
- Direct market value (DMV) in €/ha/yr (in 2023)
- Adjusted unit value (AUV) in €/ha/yr (in 2023)

Main results

The results of the economic assessment for timber wood biomass of the different living labs are compiled in the table below.

Table 12: Main results for economic valuation of fire wood biomass

Indicators and Data used	Unit	Tanaro Valley, IT	Endlhausen, DE	Waakirchen, DE	Thannhausen, AT	Tržič, SI
Total forest area	ha	43,356	23,361	8,060	2,127	11,829
Logging potential	DE, AT: solid cubic meter IT, SI: m ³	1,004,201	53,492	18,456	4,772	4,140
Direct market value (DMV)	€/ha/yr	64.84	62.97	62.97	85.40	23.1
Adjusted unit value (AUV)	€/ha/yr	15.29	16.96	16.96	93.64	13.99

5.2.1 Conclusion for all living labs

Based on the assessed values for firewood biomass these conclusions are valid for all LLs:

- **Overlap with other ecosystem services:** The forest area providing firewood biomass fully overlaps with timber wood biomass provision (i.e., total forest area). In all LLs, firewood biomass was excluded from the total economic value (TEV) analysis to avoid double counting and an inflated valuation of provisioning services. In addition, only a limited subset of non-provisioning FES could be valued in TEV

terms, and these estimates were considered likely underestimated due to indicator limitations and data scarcity.

- **Contribution to forest total economic value:** Across all LLs, the relative social importance of firewood biomass remained low compared to other forest ecosystem services. Even where market price valuation increased the estimated contribution of firewood, the service remained among the lowest-ranked FES and did not alter the overall hierarchy dominated by regulating services.
- **Monetary valuation sensitivity:** The estimated social value of firewood biomass showed high sensitivity to the applied valuation method in all LLs. Comparisons between market price valuation and adjusted unit value transfer demonstrated substantial differences in per-hectare estimates, indicating that Alpine average values may either underrepresent or overestimate the local economic relevance of firewood depending on the LL.

5.2.2 *Specific conclusions for single living labs*

Austria:

- Market price valuation produced substantially higher per-hectare values for firewood biomass than the adjusted unit value transfer, indicating that Alpine average values considerably underestimate the local economic relevance of firewood. Although the absolute contribution of firewood increased under market valuation, its relative importance within the broader FES portfolio remained below dominant regulating services.

Germany

- Firewood biomass showed increased per-hectare values when upper-bound unit values incorporating direct market pricing were applied. However, compared to the other living labs, firewood remained the second least important FES in terms of social value per hectare regardless of valuation method, highlighting its particularly low relative importance in the area.

Italy

- In contrast to the other living labs, market price valuation resulted in substantially lower per-hectare estimates than the adjusted unit value transfer. This indicates that Alpine average values overestimate the local economic relevance of firewood in Italy. Nevertheless, the relative importance of firewood provision remained among the lowest compared to other FES.

Slovenia

- Slovenia exhibited the strongest difference between valuation methods, with market price valuation yielding approximately twice the per-hectare value of the adjusted unit value transfer. This suggests that Alpine average values strongly underestimate the local economic relevance of firewood. Despite this increase in absolute value, firewood provision still remained among the lowest-ranked FES within the overall portfolio.

5.3 Fuel wood biomass

Indicators and data used for the economic assessment

Main indicators which were used to assess the economic value of the ecosystem service fuel wood biomass are the total forest area and the logging potential.

- Logging potential
 - Austria: Logging potential in solid cubic meter, before losses due to processing, estimated based on the actual logging data reported for the Weiz District in solid cubic meter, before losses due to processing (Efm in German) and yearly increment reported solid cubic meters without bark (Vfm in German)
 - Italy: Logging potential in m³, estimated from the territorial forest plan
- Total forest area in ha
- Direct market value (DMV) in €/ha/yr (in 2023)
- Adjusted unit value (AUV) in €/ha/yr (in 2023)

Main results

The results of the economic assessment for timber wood biomass of the two living labs Thannhausen (AT) and Tanaro Valley (IT) are compiled the table below.

Table 13: Main results for economic valuation of fuel wood biomass

Indicators and Data used	Unit	Tanaro Valley, IT	Thannhausen, AT
Total forest area	ha	43,356	2,127
Logging potential	AT: solid cubic meter IT: m ³	1,618,929	4,772
Direct market value (DMV)	€/ha/yr	45.87	85.40
Adjusted unit value (AUV)	€/ha/yr	81.95	93.64

5.3.1 Conclusion for all living labs

Based on the assessed values for fuel wood biomass these conclusions are valid for all LLs:

- **Overlap with other ecosystem services:** The forest area providing fuelwood biomass fully overlaps with timber wood biomass provision (i.e., total forest area). To avoid double counting and an inflated valuation of provisioning services, fuelwood biomass was excluded from the TEV analysis in all living labs. In addition, only a limited subset of non-provisioning FES could be valued in TEV terms, and these estimates were likely underestimated due to indicator limitations and data scarcity.
- **Contribution to forest total economic value:** Fuelwood biomass showed low relative social importance in both living labs. Its value remained below dominant regulating services and also below timber provisioning services. In Italy, recreation additionally ranked above fuelwood provision. Even where differences in valuation methods affected absolute values, the overall hierarchy of FES importance did not change.
- **Monetary valuation sensitivity:** The sensitivity of fuelwood biomass valuation differed between living labs.

5.3.2 Specific conclusions for single living labs

Austria

- Fuelwood biomass in Austria showed low sensitivity to the valuation method, as market price valuation and adjusted unit value transfer produced almost identical unit values. This indicates that Alpine average estimates reflect local conditions relatively well. Despite this consistency, fuelwood remained of low relative social importance compared to regulating, cultural, and timber provisioning services.

Italy

- Fuelwood biomass in Italy showed high sensitivity to the valuation method, with market price valuation producing values almost half as high as the adjusted unit value transfer. This suggests that Alpine average values considerably overestimate the local economic relevance of fuelwood. Although the adjusted unit value transfer increased the absolute value of the service, fuelwood still remained below regulating services, timber provision, and recreation in the overall FES hierarchy.

5.4 Provision of habitats for wild plants and animals

Indicators and data used for the economic assessment

Main indicators which were used to assess the economic value of the ecosystem service provision of habitats for wild plants and animals are the concerned area in ha and %

- Concerned area in ha and % of total forested area (see section 4.3 for more details on the area)
- Adjusted unit value (AUV) in €/ha/yr (in 2023), for the German living labs two adjusted unit values were calculated: the Alpine area average (AUV₁) and the adjusted unit value in €/ha/yr (in 2023), from the primary valuation study conducted in Germany on the national scale (AUV₂)
- Total economic value (TEV) in €/yr (2023), for the German living lab the TEV was calculated based on AUV₁ and AUV₂

Main results

The results of the economic assessment for timber wood biomass of the different living labs are compiled in the table below.

Table 14: Main results for economic valuation of provision of habitats for wild plants and animals

Indicators	Unit	Grand Anney, FR	Thonon, FR	Tanaro Valley, IT	Endl-hausen, DE	Waa-kirchen, DE	Thann-hausen, AT
Concerned area	ha	1,299	1,333	43,356	2,298	1,718	205
	% of total forested area	5.0	13.8	100	9.8	21.3	9.6
Adjusted unit value (AUV, AUV ₁ , AUV ₂)	€/ha/yr	409.44	409.44	356.85	395.88 (AUV ₁) 1168.76 (AUV ₂)	395.88 (AUV ₁) 1168.76 (AUV ₂)	407.73
Total economic value (TEV, TEV ₁ , TEV ₂)	€/yr	532,109	545,930	15,471,732	909,571.37 (TEV ₁) 3,537,155.59 (TEV ₂)	680,033 (TEV ₁) 2,007,645 (TEV ₂)	83,571

5.4.1 *Conclusion for all living labs*

Based on the assessed values for the provision of habitats for wild plants and animals these conclusions are valid for all LLs:

- **Overlap with other ecosystem services:** Habitat provision strongly overlaps with other forest ecosystem services, particularly timber provision and carbon sequestration. For Austria, Germany and France, it must be noted that only areas with high habitat value were included (see section 4.3) while in principle all forests provide habitats of varying quality. This indicates the importance of a multifunctional forest management approach and suggests that the assessed contribution may underestimate the broader ecological role of forests for biodiversity provision. Other indicators of biodiversity could help draw a fuller picture.
- **Contribution to forest total economic value:** Across most living labs, habitat provision achieved high per-hectare values, reflecting strong societal relevance. However, its contribution to total economic value (TEV) was often constrained by the comparatively small spatial extent of forests classified as high-value habitat areas. Consequently, a divergence emerged between high relative value per hectare and lower overall contribution to TEV. Italy represented an exception, where the entire living lab area was designated as Natura 2000 habitat, resulting in habitat provision becoming one of the largest contributors to TEV.
- **Monetary valuation sensitivity:** The valuation results indicate that habitat provision may be underestimated when relying on adjusted Alpine average values. In Germany, upper-bound estimates based on national primary studies substantially increased the estimated FES value compared to conservative assumptions. This suggests that valuation methodology has a strong influence on estimated economic values and that adjusted unit value transfers may not fully capture the local societal importance of habitat provision.

5.4.2 *Specific conclusions for single living labs*

Austria

- Habitat provision in Austria achieved one of the highest per-hectare valuations, indicating strong societal importance. However, because only a limited forest area with high habitat value was included, its contribution to total economic value remained comparatively small. The results suggest that expanding habitat-relevant forest areas would proportionally increase its contribution to TEV.

Germany

- In Germany, habitat provision showed very high local relevance, with upper-bound estimates from national primary studies substantially increasing the estimated value compared to adjusted Alpine averages. Despite high per-hectare values, the contribution to TEV remained limited in some areas because habitat-providing forests covered only a comparatively small spatial extent. Expanding these areas would significantly increase the total economic value of the service.

France

- France also exhibited high per-hectare values for habitat provision, reflecting strong societal importance. Nevertheless, the overall contribution to TEV was relatively low due to the limited area classified as high-value habitat forest. The results indicate that the low total contribution is mainly linked to spatial constraints rather than low societal valuation.

Italy

- Habitat provision in Italy was among the most highly valued regulating FES on a per-hectare basis and became one of the largest contributors to TEV. This was mainly because the entire living lab area is designated as Natura 2000 habitat. In addition, habitat provision completely overlapped with timber provision and carbon sequestration, highlighting the importance of multifunctional forest management and potential interactions between ecosystem services.

5.5 CO₂ storage and sequestration in forests

Indicators and data used for the economic assessment

In the following are listed the main indicators which were used to assess the economic value of the ecosystem service CO₂ storage and sequestration.

- Total forest area in ha
- Mean sequestered carbon in tCO₂/ha
- Average price on Italian carbon voluntary market in €/tCO₂ and in €/ha, adjusted to inflation, using consumer price index (VCMP)
- Upper-bound price in €/tCO₂ and in €/ha of the price range recommended by the High-Level commission on Carbon Prices to limit temperature rise to well below 2 °C adjusted to the economic conditions in Italy, using PPP conversion factor (RCP, upper-bound)
- Total economic values in €/yr (2023)

Main results

The results of the economic assessment for CO₂ storage and sequestration of the different living labs are compiled the table below.

Table 15: Main results for economic valuation of the service CO₂ storage and sequestration

Indicators and data used	Unit	Grand Anney, FR	Thonon, FR	Tanaro Valley, IT	Endl-hausen DE	Waa-kirchen, DE	Thann-hausen, AT
Total forested area	ha	26,209	9,696	43,356	23,361	8,060	2,127
Mean sequestered carbon	tCO ₂ /ha	3.10	2.26	3.45	7.53	7.53	5.49
VCMP	€/tCO ₂	18.96	18.96	29.72	18.33	18.33	18.88
	€/ha	58.83	42.90	102.63	138.12	138.12	103.67
Total economic value (VCMP)	€/yr	1,541,962	415,939	4,449,597	3,226,707	1,113,275	220,481
RCP, upper-bound	tCO ₂ /ha	98.01	98.01	85.42	94.76	94.76	97.60
	€/tCO ₂	304.11	221.73	294.96	713.94	713.94	535.88
Total economic value (RCP, upper-bound)	€/yr	7,970,254	2,149,950	12,788,421	16,678,541	5,754,411	1,139,645

5.5.1 Conclusion for all living labs

Based on the assessed values for the ecosystem service *CO₂ storage and carbon sequestration*, these conclusions are valid for all LLs:

- **Overlap with other ecosystem services:** Forest areas providing carbon sequestration strongly overlap with areas used for timber production and, in some living labs, also with habitat provision. This indicates that forest management decisions targeting timber extraction directly influence the social value derived from carbon sequestration. The results highlight the importance of multifunctional forest management approaches that balance climate mitigation, timber production, and biodiversity-related ecosystem services.
- **Contribution to forest total economic value:** CO₂ sequestration represents a major contributor to total economic value (TEV) in all living labs, particularly under pricing approaches aligned with Paris Agreement climate mitigation targets. Depending on the applied pricing assumptions, the contribution of carbon sequestration to TEV increases substantially and, in several cases, becomes one of the principal contributors to overall forest economic value. This demonstrates the strong societal importance of climate regulation services in forest ecosystems.
- **Monetary valuation sensitivity:** The economic valuation of CO₂ sequestration is highly sensitive to the applied carbon pricing method in all living labs. Valuation based on recommended carbon prices consistently produced substantially higher per-hectare values than voluntary carbon market pricing. Under conservative voluntary market assumptions, carbon sequestration was often valued similarly to or below timber provisioning services, whereas recommended pricing scenarios elevated it to one of the highest-valued regulating ecosystem services. These differences demonstrate the strong influence of pricing assumptions on the estimated social and economic relevance of carbon sequestration.

5.5.2 Specific conclusions for single living labs

Austria

- High valuation sensitivity to carbon pricing assumptions: Valuation outcomes differ substantially depending on whether voluntary carbon market pricing or recommended carbon pricing is applied. Using recommended prices increases the unit value from the lower range (below timber values) to the third highest valued FES among all regulating services.
- Strong influence on TEV composition: Under voluntary pricing, CO₂ sequestration contributes 18 % to total economic value; under recommended pricing, it rises to 46 %, however, does not significantly increase the total economic value of the LL forests.
- Spatial overlap with timber and habitat provision: The same forest area supplies both CO₂ sequestration, habitat provisioning and timber provisioning services. Management strategies oriented strongly toward timber extraction therefore carry implications for carbon-related social value, particularly under the higher recommended carbon price scenario. At the same time, strategies aimed at capturing the value of carbon sequestration should not conflict with biodiversity and reduce value of habitats.

France

- High valuation sensitivity to carbon pricing assumptions: Conservative valuation based on voluntary carbon market pricing places CO₂ sequestration among the lower-valued services per hectare. When upper-bound recommended carbon pricing is applied, its per-hectare value rises significantly,

positioning it among the three and five most valuable regulating services in Annecy and Thonon Living Labs respectively.

- Influence on total economic value: CO₂ sequestration contributes substantially to total economic value under upper-bound pricing scenarios, reflecting its high societal importance when climate mitigation considerations are accounted for.
- Overlap with provisioning areas: The forest area providing carbon sequestration fully coincides with zones supplying timber and partially overlaps with other FES. Management strategies oriented primarily toward timber or other provisioning services may therefore affect the overall social value of carbon storage.

Germany

- Sensitivity to pricing assumptions: The valuation of CO₂ sequestration varies substantially depending on the pricing method. Recommended carbon pricing yields a per-hectare value approximately five times higher than voluntary carbon market pricing, while voluntary carbon market values this FES in the same price range as provision of timber wood biomass (using Alpine average estimates)
- Significant TEV contribution: Using pricing compliant with Paris Agreement climate change mitigation targets, CO₂ sequestration accounts for around 49 % and 44 % of TEVs in Endlhausen and Waakirchen, respectively, making this FES a principal contributor to total forest values of German Living Labs.
- Spatial overlap with timber: The forest area that sequesters carbon fully overlaps with the area used for timber production. Forest management decisions targeting timber extraction therefore directly influence the social value from carbon sequestration.

Italy

- Sensitivity to pricing assumptions: The valuation of CO₂ sequestration varies substantially depending on the pricing method. Recommended carbon pricing yields a per-hectare value almost three times higher than pricing on the Italian voluntary carbon market. Local market values carbon sequestration significantly lower than timber, while pricing compliant with Paris Agreement climate change mitigation targets makes this FES top fourth most socially relevant in the FES portfolio.
- Significant TEV contribution: Using pricing compliant with Paris Agreement climate change mitigation targets, CO₂ sequestration accounts for around 36 % of TEV, making the principal contributors to total forest value.
- Spatial overlap with timber: The forest area that sequesters carbon fully overlaps with the area used for timber production. Forest management decisions targeting timber extraction therefore directly influence the social value from carbon sequestration.

5.6 Natural hazard prevention, mitigation and control

The following chapter describes the economic assessment of natural hazard prevention, mitigation and control for the two ecosystem services Prevention against rockfalls and Torrents control, where prevention against rockfall was calculated for Grand Annecy, France and Endlhausen and Waakirchen, Germany and Torrents control for Trzic, Slovenia.

5.6.1 Prevention against rockfalls

Indicators and data used for the economic assessment of prevention against rockfall

The following data was used for the economic assessment of prevention against rockfalls:

- Concerned area (protective forest) in ha and % of total forested area
- Adjusted unit value in €/ha/yr (in 2023), the Alpine area average (AUV₁)
- Adjusted unit value in €/ha/yr (in 2023), based on the estimates provided by the 2011 Interreg France–Switzerland Protective Forest (AUV₂)
- Total economic values TEV₁ and TEV₂ in €/yr (2023)

Main results

The results of the economic assessment are compiled the table below.

Table 16: Main results for economic valuation of the prevention against rockfall in France and Germany.

Indicator	Unit	Annecy, FR	Waakirchen, DE
Concerned area	ha	8,688	-
	% of total forested area	35.2	-
AUV ₁	€/ha/yr	1,258.92	1,217.24
AUV ₂	€/ha/yr	427.85	-
Total economic value (TEV ₁)	€/yr	10,938,027	-
Total economic value (TEV ₂)	€/yr	3,717,357	-

Conclusions for the French living lab

- High social relevance and sensitivity to valuation method: Data used for adjusted unit value transfer has a big influence on the valuation result, as the more local estimates provide a value more than twice lower than Alpine average. Nevertheless, regardless of the data used, this ecosystem service is among the most socially relevant (per ha) in the LL areas.
- Significant contribution to total economic value in different value scenarios: When upper-bound estimates are used, protection against rockfalls becomes one of the largest contributors to total economic value. This FES valued with the lower local estimates nevertheless is among top three comparable contributors to the conservative TEV.
- No data for concerned forest area was provided for the Thonon Living Lab

Conclusion for the German living lab

- High social relevance: In the Alpine context, the prevention against rockfalls has the highest social value per ha of forest in the German living lab, thereby highlighting a particular relevance of these services for the region.
- In the Large Scale Assessment (s. chapter 4.5, Table 6) the share of forest area, which provides prevention against rockfall is not existent in the German living lab, although the ecosystem service has been analysed in the Local Scale Assessment based on local data (see Chapter 4.5). This ecosystem service is of great importance to the living lab part Waakirchen.

5.6.2 Torrents control

Indicators and data used for the assessment of the torrent control

The economic assessment for the ecosystem service natural hazard prevention, mitigation and control, specifically torrents control, has been carried out only for the Slovenian living lab. The following data was used for the economic assessment:

- Concerned area (40m buffer area around torrents) in ha and % of total forested area
- Adjusted unit value in €/ha/yr (in 2023) of flood control²
- Total economic values in €/yr (2023)

Main results

The results of the economic assessment of torrent control are compiled the table below.

Table 17: Main results for economic valuation of torrents control

Indicator	Unit	Tržic, SI
Concerned area	ha	2,807
	% of total forested area	23.7
AUV	€/ha/yr	839.05
Total economic value	€/yr	2,355,048

Conclusions for the Slovenian living lab

- High social relevance: Torrent control, or flood control, FES is estimated to be the second most relevant (per ha) FES in the area, however, its overall contribution to the total economic value remains moderate, which is rather a reflection of the forest area used for analysis, not the social value of the service. Increasing the size of the buffer area around torrents dedicated to the provision of this service could substantially increase the total economic value of the forests in the area.

5.7 Maintenance of high-quality fresh waters (Water filtration)

This ecosystem service maintenance of high-quality fresh water (water filtration) was of relevance only in the French living lab. The assessment of the ecosystem services is outlined below.

² As there are no valuation studies looking specifically into torrent control, it was decided to take existing values for the broader FES of flood control.

Indicators and data used for the assessment in France

The following data was used for the economic assessment of water filtration:

- Adjusted unit value in €/ha/yr (in 2023), the Alpine area average (AUV₁)
- Adjusted unit value in €/ha/yr (in 2023), based on the locally used values (AUV₂)

Main results

The results of the economic assessment of water filtration are compiled the table below.

Table 18: Main results for economic valuation of maintenance of high-quality fresh waters

Living Lab	Indicator	Unit	Value
Annecy and Thonon	AUV1	€/ha/yr	82.94
	AUV2	€/ha/yr	26.72

5.7.1 Conclusion for the French living lab

- Sensitivity to valuation method: Unit value and its relative importance in the set of FES is dependent on data choice, as data used locally in the Living Lab areas is more than three times lower than Alpine average value.
- Relatively low social importance: Regardless of the method used, FES is among the least valued ones, losing to most regulating and timber provisioning services.
- Spatial interplay with water provision: Areas offering water filtration often coincide with zones of water provision. This reinforces the importance of considering multiple hydrological services jointly when evaluating management options.

5.8 Recreation

Indicators and data used for the economic assessment

Main indicators which were used to assess the economic value of the ecosystem service recreation are the concerned area in ha and %.

- Concerned area in ha and % of total forested area
- Adjusted unit value in €/ha/yr (in 2023)
- Total economic values in €/yr (2023)

Main results

The results of the economic assessment for recreation are compiled the table below.

Table 19: Main results for economic valuation of recreation in the living labs

Indicators	Unit	Grand Anancy, FR	Thonon, FR	Tanaro Valley, IT	Endlhausen DE	Waakirchen, DE	Trzic, SI
Concerned area	ha	22,945.33	9,409.60	19,879.04	14,390.24	4,699.71	4,414.47
	% of total forested area	87.6	97	45.9%	61.6	58.3	37.3%
Adjusted unit value	€/ha/yr	271.22	271.22	236.39	262.24	262.24	216.38
Total economic value	€/yr	6,223,321	2,552,108	4,699,196	3,773,744	1,232,467	955,220

5.8.1 Conclusion for all living labs

Based on the assessed values for the ecosystem service recreation these conclusions are valid for all LLs:

- **Overlap with other ecosystem services:** Recreational forest areas show substantial spatial overlap with productive forests used for timber provision. In several living labs, more than half of forests with recreational value coincide with timber production areas, indicating potential trade-offs between recreation and forest management strategies focused on timber extraction. In some cases, recreation additionally overlaps with carbon sequestration and habitat provision, highlighting the need for multifunctional forest management approaches to avoid reductions in overall forest economic value.
- **Contribution to forest total economic value:** Recreation contributes substantially to total economic value (TEV) in several living labs, particularly where large forest areas are accessible for recreational use. Its contribution is often driven more by the spatial extent of recreation-providing forests than by exceptionally high per-hectare values. There are differences between the Living Labs in terms of their contribution to the TEV.
- **Monetary valuation sensitivity:** The relative importance of recreation changes depending on the valuation scenario applied. Under conservative assumptions, recreation can represent one of the dominant contributors to TEV due to its broad spatial availability. However, under upper-bound scenarios, the contribution of recreation often declines relative to ecosystem services with substantially higher per-hectare values, such as carbon sequestration or protective services. This demonstrates that the perceived economic relevance of recreation is sensitive to the valuation framework and to comparisons with other highly valued forest ecosystem services.

5.8.2 *Specific conclusions for single living labs*

France

Conclusions for Annecy Living Lab:

- Largest contributor to conservative TEV: Recreation contributes the most to the conservative total economic value³, reflecting both its relatively high unit value and the substantial forest area that provides this service within Grand Annecy.
- Spatial concentration around key landscape features: Forest areas with higher recreational value per hectare cluster around Annecy Lake and in southern and eastern zones of the region. These patterns highlight the link between recreational demand and specific landscape characteristics.
- Spatial overall with timber: majority of forests with recreational value overlap with productive forest, indicating potential trade-offs and sensitivity of this FES to forest management strategies focusing on timber extraction.

Conclusions for Thonon Living Lab:

- Largest contributor to TEV: Recreation contributes the most to the total economic value in both scenarios (conservative and upper-bound), reflecting both its relatively high unit value and the substantial forest area that provides this service within Thonon.
- Spatial concentration around key landscape features: Forest areas with higher recreational value per hectare cluster around Ripaille Forest (Forêt de Ripaille), in the southern tip of Agglomeration where residents and visitors can access Thonon Forest, and in a few residential areas. These patterns highlight the link between recreational demand and specific landscape characteristics.
- Spatial overall with timber: majority of forests with recreational value overlap with productive forest, indicating potential trade-offs and sensitivity of this FES to forest management strategies focusing on timber extraction.

Germany

Conclusions for the Endlhausen Living Lab:

- Substantial to minor share of TEVs: Recreation represents 32% of TEV under conservative assumptions⁴, reflecting the extensive area of forest accessible for recreational use. The magnitude of this contribution is driven by spatial availability rather than high per-hectare values, which becomes evident in the upper-bound TEV, where the relative contribution to it decreases by 11% with other FES with higher unit values overtaking it.

³ For the French Living Labs, conservative total economic value was calculated using lowest available unit value estimates of FES, included in TEV analysis, which concerned only protection against rockfall and carbon sequestration as the only FES in the French Living Labs that had both conservative and upper-bound unit values. Thereby, an upper-bound total economic value was estimated using the upper-bound unit values of these two FES, while values for other FES, included in the analysis, remained the same. For more detail, see D 2.3.1.

⁴ For the German Living Labs, conservative total economic value was calculated using lowest available unit value estimates of FES, included in TEV analysis, which concerned only provision of habitats for wild plants and animals and carbon sequestration as the only FES in the German Living Labs that had both conservative and upper-bound unit values. Thereby, an upper-bound total economic value was estimated using the upper-bound unit values of these two FES, while values for other FES, included in the analysis, remained the same. For more detail, see D 2.3.1.

- Spatial overlap with timber: over 60% of forests with recreational value overlap with productive forest, indicating potential trade-offs and sensitivity of this FES to forest management strategies focusing on timber extraction.

Conclusions for the Waakirchen Living Lab:

- Comparable to minor contribution to TEVs: Recreation represents 23% of TEV under conservative assumptions, reflecting the extensive area of forest accessible for recreational use. This contribution is comparable with other FES, as all of them contribute more or less evenly to a conservative TEV. The magnitude of this contribution is driven by spatial availability rather than high per-hectare values. However, under upper-bound assumptions, contribution of recreation to TEV is significantly reduced to 8%, as FES with higher per unit values gain in weight.
- Spatial overlap with timber: almost 60% of forests with recreational value overlap with productive forest, indicating potential trade-offs and sensitivity of this FES to forest management strategies focusing on timber extraction.

Italy

- Moderate social relevance in the overall portfolio of FES: Although the unit value is relatively high, as this FES consistently remains within top four most highly valued services, the total contribution to TEV is relatively small. This is regardless of the fact that almost half of the total forest area is provides this FES, which is a reflection of both comparatively moderate per unit value (compare to the value per ha of protection against rockfall, which is 1098 €/ha) and relatively moderate size of forest valuable for recreation, while three (out of five) other FES with similar per unit value occupy total forest area.
- Spatial overlap: 46% overlap with timber provision, carbon sequestration and habitat provision could cause significant conflicts in forest management, as focus on one of these FES could cause trade-offs in their provision and trigger a dramatic loss in the total economic value of the forest.

Slovenia

- Moderate social relevance in the overall portfolio of FES: Depending on the valuation scenario, the social value per ha ranges between top fourth and sixth FES in the portfolio, losing to carbon sequestration and timber provision in upper-bound scenario.
- Marginal contribution to total economic value: Irrespective of valuation scenario, this FES remains a consistently marginal contributor to TEV, ranging between 5 and 9%.

6 Transnational conclusions for the Alpine area

In this chapter conclusions from a transnational perspective are drawn on the living lab insights. There may be similarities but also differences between the living lab sites. As a matter of course, such a transnational perspective has to consider different ecological and social conditions in the living labs. Therefore the conclusions are based mainly on values which are calculated on a comparable basis, such as per hectare or per year.

As the living lab areas are of very different size, values for total areas are not very significant, as they depend mainly on the forest area which was assessed.

However, some main observations are possible and could offer other Alpine areas some insights which ecosystem services are of particular importance and would be easier to increase or implement their maintenance.

In the following the transnational conclusions are drawn for the ecosystem services provision of timber wood biomass, provision of habitats for wild plants and animals, CO₂ storage and sequestration, Natural hazard prevention, Maintenance of high-quality fresh waters and recreation.

6.1 Timber wood biomass

Since the provision of fuel wood, firewood, and timber wood was assessed using the same underlying dataset representing logging potential, with all indicators expressed as mean growing stock volume, the following analysis focuses exclusively on timber wood, while fuel wood and firewood are not considered separately.

Biophysical assessment

The production output of the forest is primarily determined by the provision of wood as a raw material. The wood obtained during felling can be categorised as stem wood, energy wood, industrial wood and non-utilisable wood. Sustainable timber production and utilisation ensures that the amount of timber harvested does not exceed the annual growth. This ensures a constant supply of the raw material.

The overall comparison of the living labs in **Figure 14** represents the high share of wood biomass increment in the coniferous dominated Austrian and German living lab areas.

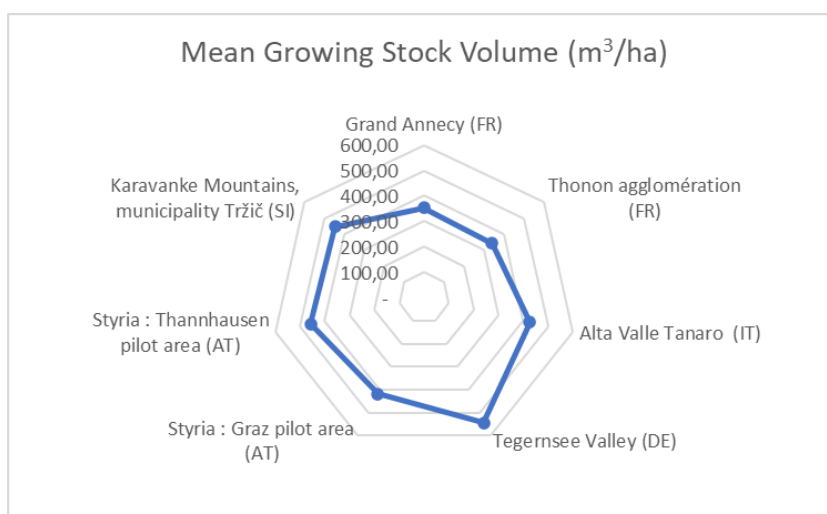


Figure 14: Comparison of Mean Growing Stock volume in the living labs.

Economic assessment

Timber wood provision of the different forest types is generally one of the most valuable FES in all pilot areas. However, often timber provision has a moderate contribution only to the total economic value for society. It is less valuable than regulating services (such as natural hazard mitigation, carbon sequestration). This becomes evident when sensitivity is particularly high, and market prices exceed Alpine average values, such as in Austria, Germany and Slovenia.

The table below (Table 20) gives an overview of main similarities and differences of the social value of timber provision in the five different living lab areas.

Table 20: Comparison of timberwood provision

Living Lab country	Direct market value (€/ha/yr)	Adjusted unit value (€/ha/yr)	Contribution to forest total economic value (TEV)	Sensitivity to valuation method
Austria	314.61	173.74	High contribution to TEV: timber is estimate about 30% of TEV.	High: market prices exceed average Alpine values
France	-	174.46	Moderate contribution to TEV: regulating services are clearly more valuable	No market prices available
Germany	461.92	168.69	Moderate contribution to TEV: timber is largest single contributor, contributing with less than 30%.	High: value increases three-fold when local market prices are applied
Italy	1,543.64	152.06	Moderate contribution to TEV, contributing with about 20 % to TEV.	Low: values from transfer method meet the local price level
Slovenia	393.72	139.19	Moderate contribution to TEV, contributing with 15 – 23 % to TEV.	High: value transfer requires great caution as cultural

Certainly commercial timber production provide always some regulating services as well but a well-balanced forest management is key for avoiding negative trade-offs. In the past forest management has been the origin for the concept of sustainable development, meaning at least, that timber extraction may not exceed natural increment.

6.2 Provision of habitats for wild plants and animals

Biophysical assessment

The biodiversity potential has been analysed on basis of forest areas, riparian forests and protected areas. The graph in Figure 15 shows a high share of area in the Slovenian and Italian living lab.

Certainly, this is strongly influenced by the delineation of the LL territory, in particular whether there are designated protected areas. The Natura2000 sites are only a proxy at a transnational level. Also the selection of protection status will have a strong influence, so national and regional protection schemes will alter this. Finally, the protection status does not directly influence the biodiversity relevance of a forest, there are also highly relevant forests without protection status.

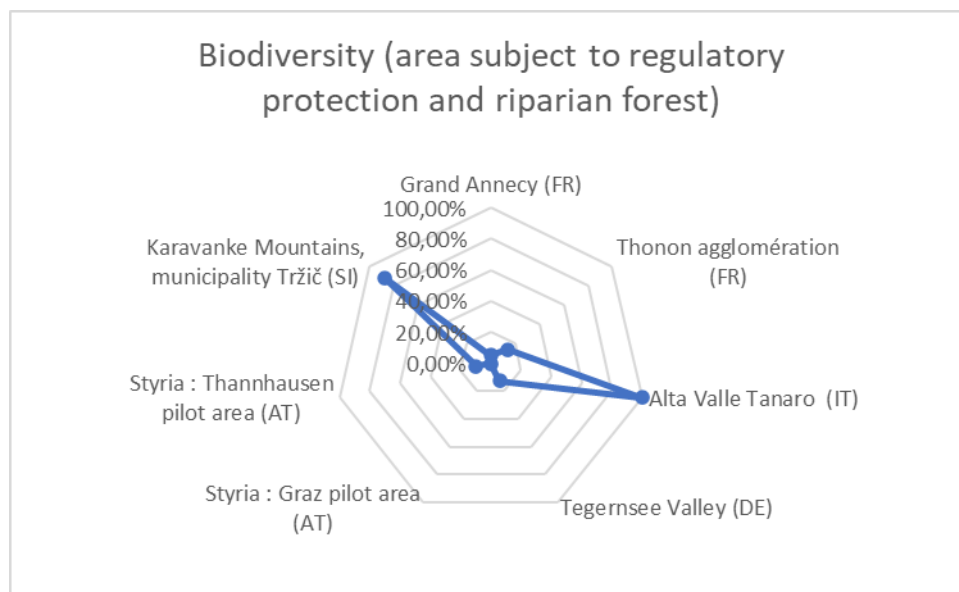


Figure 15: Comparison of biodiversity provision in share of forest area

Economic assessment

The provision of habitats for wild plants and animals is one of the ecosystem services with the highest per-hectare value. The total value of an area however depends on the surface area and, as near-nature forests with high habitat provision are diminished in favour of commercially used forests, the total values are rather low. An exemption is the Italian living lab with 100% of forests with habitat provision (cf. Table 21).

From an economic point of view, the increase of near-nature forests in size would increase the total value of forest offering this ecosystem service.

Table 21: Comparison of habitat provision for wild plants and animals

Living Lab country	Adjusted unit value (€/ha/yr)	% of total forested area	FES forest area, ha	FES economic value for the area €/yr
Austria	407.73	9.6%	204.97	83,571.48
France				
Annecy	409.44	5.0 %	1,299,60	532,109.04
Thonon		13.8%	1,333.36	545,930.49
Germany				
Endlhausen	395.88 ⁵	9.8	2,298	909,571.37
Waakirchen		21.3	1,718	680,033
Italy	356.85	100 %	43,356	15,471,732

⁵ In Table 21 only the AUV₁ for Germany is presented, which is the alpine area average. The adjusted unit value from the primary valuation study conducted in Germany on the national scale (AUV₂) is only presented in Table 14.

6.3 CO₂ storage and sequestration in forests

Biophysical assessment

The ecosystem service describes the ability of forests to absorb carbon dioxide (CO₂) from the atmosphere and bind it in the long term. This happens through the process of photosynthesis, in which trees absorb CO₂ and store it in the form of carbon in wood, leaves and roots. The indicator best suited to describe the ecosystem service is ton of carbon per hectare (t C / ha) and describes the amount of carbon (C) that is stored or sequestered per hectare (ha).

The graph in Figure 16 shows high values for the German and Austrian Living Lab, which may be an effect of higher shares of coniferous forests in these areas and / or less fertile areas in other living labs particularly in France.

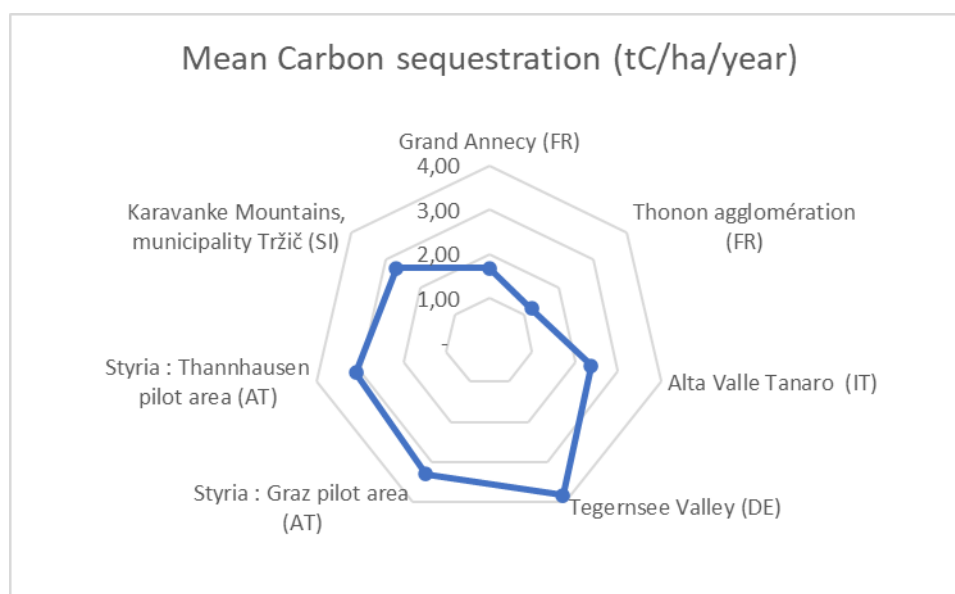


Figure 16: Mean carbon sequestration in the living labs.

Economic assessment

The valuation of the ecosystem service CO₂ storage and sequestration is very sensitive to the pricing model which is used. The upper-bound prices recommended by the High-Level commission on carbon prices (RCP) are about 10 - 40 times higher than prices on the voluntary market (VCMP) (cf. Table 22). The first ones are following the objective to limit climate change caused temperature rise below 2° C. Accordingly economic values for this ecosystem service differ significantly and can be the major part of the total economic value (between 36 – 44%), if RCP prices are applied.

Table 22: Comparison of CO₂ storage and sequestration

Living Lab country	VCMP €/ha	Total economic value (VCMP) €/yr	VCMP €/tCO ₂	RCP, upper-bound €/tCO ₂	Total economic value (RCP, upper-bound) €/yr
Austria	103.67	220,481	18.88	535.88	1,139,645
France					
Anancy	58.83	1,541,962	18.96	304.11	7,970,254
Thonon	42.90	415,939		221.73	2,149,950

Germany					
Waakirchen	138.12	1,113,275	18.33	713.94	5,754,411
Endlhausen		3,226,707			16,678,541
Italy	102.63	4,449,597	29.72 ⁶	294.96	12,788,421

The forest area that sequesters carbon fully overlaps with the area used for timber production. Forest management decisions targeting timber extraction therefore directly influence the social value from carbon sequestration.

6.4 Natural hazard prevention, mitigation and control

6.4.1 Prevention against rockfalls

Biophysical assessment

The ecosystem service of natural hazard prevention, mitigation and control has been assessed on local and large-scale level. The results of forest ecosystem services assessment and the potential effects of forest management on ecosystem services supply are presented in D2.2.1 Forest Ecosystem services assessment pilot action report and are summarized here.

The share of forests with protection function against rockfall risk is presented in Figure 17. The French Living lab part of Grand Anancy has a very high share. This may be caused by the combination of steep rock valley shoulders and a relatively dense peri-urban settlement pattern in Grand Anancy. Whereas in the Tegernsee Valley there are relatively low and soft valley shoulders.

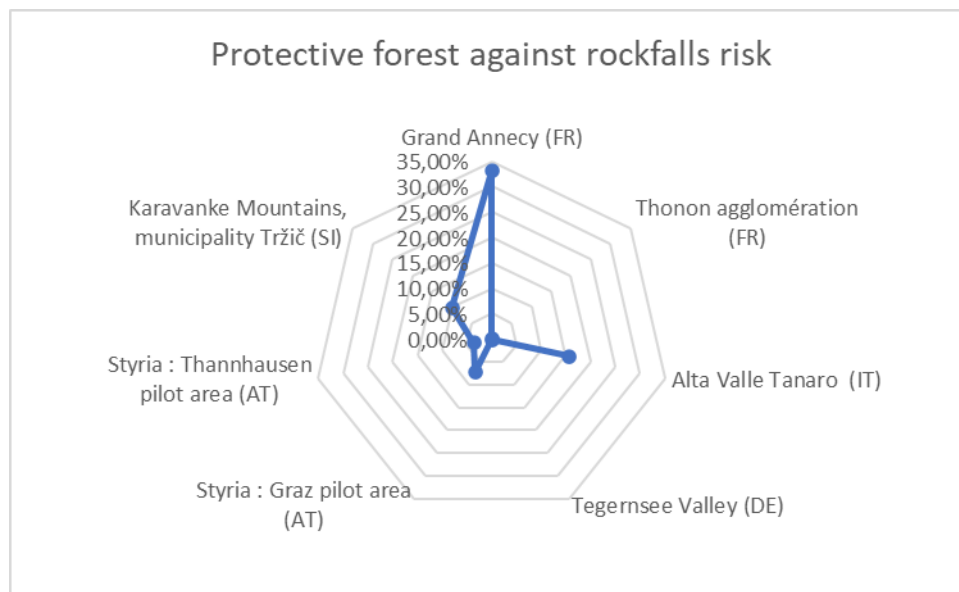


Figure 17: Regulation of rockfall risk by forests.

Economic assessment

The economic relevance was assessed using Adjusted Unit Values (AUV), based on the Alpine average (AUV₁), in case of the French living lab area a second one based on estimations by the 2011 Interreg project France-Switzerland (AUV₂).

⁶ A market price of t CO₂ in Italy based on the 2022 price of 28.15 €/t CO₂, adjusted for inflation.

Table 23: Comparison of the economic values for the ecosystem service protection against rockfall

Living Lab country	AUV 1 in €/ha/yr	AUV 2 in €/ha/yr
France	1,258.92	427.85
Germany	1,217.24	-

In general, protection rockfall exhibits to the highest (FR, DE) among the assessed ecosystem services. This reflects the high societal importance attributed to natural hazard mitigation.

6.4.2 Torrents control

Biophysical assessment

The ecosystem service of torrents control has been assessed on local and large-scale level only for the Slovenian living lab. The results of forest ecosystem services assessment and the potential effects of forest management on ecosystem services supply are presented in D2.2.1 Forest Ecosystem services assessment pilot action report and are summarized here.

Economic assessment

The economic relevance of torrent control in Slovenia was assessed using Adjusted Unit Values (AUV) derived from the Alpine average. In 2023, Slovenia's AUV for torrent control amounted to 839.05 €/ha/yr, representing a comparatively high value. Within the Alpine context, regulating services such as torrent control exhibit the highest social value per hectare of forest, underlining the substantial regional importance of this ecosystem service.

6.5 Maintenance of high-quality fresh waters (water filtration)

Biophysical assessment

The forest ecosystem service maintenance of high-quality fresh waters (water filtration) refers to the natural capacity of forest soils, vegetation, and microbial communities to retain, degrade, and remove nutrients, pollutants, and sediments from water. From a nutritional and ecological perspective, this service is essential because it safeguards drinking water quality, supports food production systems, and reduces health risks associated with contaminated freshwater resources.

Forests that play a major role in providing a high support for water resources are found primarily in Italy and Thonon agglomeration, France, whereas the living lab sites in the Karavanke Mountains, in Thannhausen and in the Tegernsee Valley make a relatively minor contribution due to the high proportion of coniferous trees, as *Figure 18* shows. Grand Annecy and the living lab in Graz, Austria occupy a middle position.

The indicator is based on the three main forest stand type categories pure broadleaved forests, mixed forests and pure coniferous forests. The result is expressed, for each site, as the percentage of the forest area concerned relative to the total forest area.

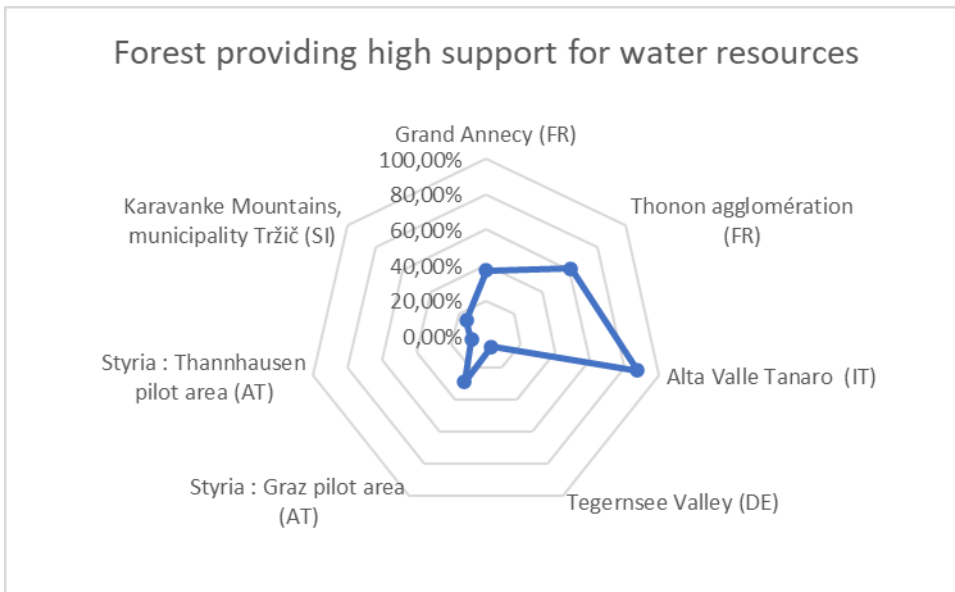


Figure 18: Maintenance of high-quality fresh waters based on the share of forest types.

Economic assessment

The Adjusted Unit Values (AUV) for the ecosystem service *maintenance of high-quality fresh waters* were comparatively low in the French living lab relative to other regulating services, as shown in Table 24. Consistent across assessment methods, it has been assigned lower social importance to freshwater filtration functions than to most regulating and timber provisioning services, indicating a comparatively limited perceived relevance within the regional socio-ecological context.

Table 24: Comparison of water filtration

Living Lab country	AUV ₁ in €/ha/yr	AUV ₂ in €/ha/yr
France	82.94	26.72

6.6 Recreation

Biophysical assessment

The forest ecosystem service recreation refers to the intangible benefits that people derive for their well-being and health from spending time in forest ecosystems. This cultural service includes opportunities for stress reduction, mental and physical regeneration as well as active and passive leisure activities in a natural environment.

Recreation is offered on most forest areas in the French living lab and in Austrian Thannhausen, but less in Slovenia, Italy and Germany, according to values displayed in Figure 19.

The indicator is based on infrastructure and viewpoints, which mean that areas with high aesthetic values and recreation potential but low infrastructure will be underestimated.

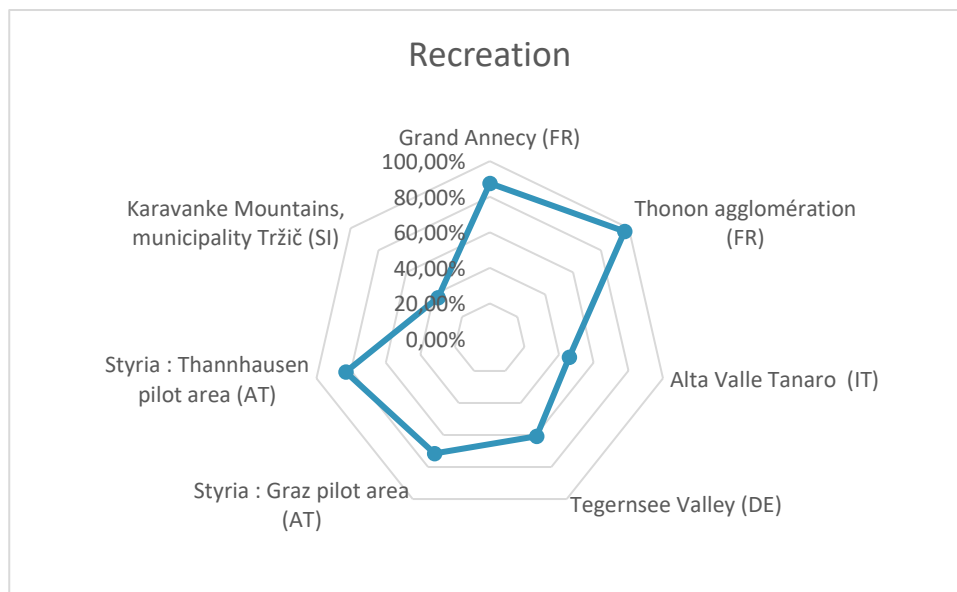


Figure 19: Cultural service recreation based on landscape aesthetic

Economic assessment

Recreation as a cultural ecosystem services becomes relevant in forest areas with special landscape amenities such as lakes, rivers, viewpoints, etc. In these cases recreation can contribute significantly to social values. Adjusted Unit Values (AUV) for recreation show the highest values in France (being close to Lake Anney and agglomeration) and lowest values in Slovenia, maybe because the Tržic area is not so close to the next agglomeration.

Table 25: Comparison of recreation

Living Lab country	AUV in €/ha/yr
France	271.22
Germany	262.24
Italy	236.39
Slovenia	216.38

Generally, in all areas recreation takes place in forests which are also used for timber production or which may be relevant for other ecosystem services. In many cases there could be synergies such as forests offering habitat services may be attractive for regeneration or aesthetic values. If there is a near-nature forest management in place also timber provision and recreation can be in place if there is no direct overlap with forest measures.

7 Value chain development in the Living labs

7.1 Overview of assessed business models

The following table gives an overview of the five living labs and their assessed business models.

Table 26: Overview of assessed business models of the living labs.

Living Lab	Business models
Germany - Tegernsee Valley, Upper Bavaria	<p><u>Burial Forest in Buchberg:</u> spiritual and cultural services will be supported through forest cemeteries with biodegradable urns</p> <p><u>Green Initiative in Waakirchen:</u> collaborative public-private partnerships will foster habitat and biodiversity conservation</p>
Austria - Province of Styria	<p><u>Reverse Auction as an Enabling Mechanism:</u> Reverse auctions serve as innovative financing mechanisms that promote biodiversity and habitat provision, as well as carbon sequestration and storage</p>
France - Haute-Savoie	<p><u>Tourism tax:</u> Securing dedicated funding from the Grand Annecy/Thonon tourism tax to co-finance recreational ecosystem services, water regulation services, and mitigate tourism impacts on local forests.</p>
Italy - Valle Tanaro, Piedmont	<p><u>Multifunctional Forest Economy for the Tanaro Valley:</u> Innovative strategies for diversified forest resource valorization, focusing on chestnut groves, non-timber products, carbon/biodiversity credits, and forest/rural heritage experiences.</p>
Slovenia - Karavanke Mountains, municipality Tržič	<p><u>Provision of wood biomass:</u> Sourcing and supplying low-quality wood from Tržič's underutilized forests to establish a local energy market and incentivize active forest management.</p> <p><u>Protection against torrents:</u> Delivering specialized, proactive forest management and monitoring services in upstream forested areas to prevent torrential floods, addressing the critical gap in coordinated preventive measures.</p> <p><u>Recreation and tourism:</u> Developing and managing diverse forest-based recreational and tourism experiences, integrating local products and addressing landowner compensation for public access.</p>

7.2 Main outcomes of the assessment in the living labs

7.2.1 Reverse auction (Austria)

Reverse auctions are a form of organizing a payment for ecosystem services scheme (PES), where landowners bid the price for providing ecosystem services or implementing sustainable management measures aimed at FES provision. Such a model, which application in environmental management has been growing in the past decades (Kindu et al., 2022), promises higher cost-efficiency, as landowners are invited to state their opportunity costs in the competitive context, i.e., they are motivated not to overestimate their costs. There are many reverse auction types, and discriminatory price auction is considered to be the most fitting one to the context of forests in the Alpine area, due to their high heterogeneity that influences opportunity costs. In such an auction, each bidder that falls within the budget threshold will be paid the price that they asked for. This way it is also possible to include other ecological and social criteria to evaluate the effectiveness of the bid. Our approach also allowed to reward forest owners who already have experience with biodiversity and carbon stability measures, as they are nudged towards thinking about their real opportunity costs, not profit generation, while those who had no prior experience were encouraged to look at their forests differently – through the lens of most biodiverse rich trees and possibilities to implement continuous cover forestry.

In the Austrian Living Lab, we invited all private forest owners of the state of Styria to make their bids for two forest management measures – deadwood/biotope trees and transformation of secondary spruce monocultures into a continuous cover forestry. The first measure was targeting provision of habitats for wild plants and animals; the second measure was targeting CO₂ storage and sequestration through stabilizing the forest ecosystem (i.e., increasing ecosystem resilience, reducing the risk of bark beetle attacks, planting species fitting to new climate, etc.). The criteria used in the evaluation of the applications are provided below for each measure (s. Table 27).

Table 27: Criteria for evaluation of the reverse auction applications.

Measure	Criteria type	Criteria	Rational
Deadwood and biotope trees	Economic	Requested funding	Cost-efficiency
	Ecologic	Duration of tree preservation, min 20 years	Leaving deadwood in forests below 20 years has low ecologic value, while longer commitment to keeping the tree in the forest creates habitat for more plants and animals
		Diameter	Thicker trees create more habitat for plants and animals
		Height	Higher trees create more habitat for plants and animals
		Health status (living and healthy – living and sick – recently dead – rotten)	While sick trees provide more habitat for plants and animals, rotten trees will not stay long in the forest, therefore, provide less ecological value
		Tree species quality	Species that are less common in Styrian forests are encouraged
		Microhabitat abundance	Presence of branches, tree wounds, tree hollows, etc. provides more habitat for plants and animals

Measure	Criteria type	Criteria	Rational
	Social	Total size of forest property(ies)	While everyone can participate, forest owners who have higher opportunity costs with less resources to apply for governmental subsidies and other forms of support are prioritized (Engel et al., 2008; Namirembe et al., 2014; Pagiola et al., 2008; Wegner, 2016)
Transformation of secondary spruce monocultures into a continuous cover forestry	Economic	Requested funding per ha of transformation plot	Cost-efficiency
		Harvesting maturity	Forest plots mature or nearly mature for harvesting are discouraged as the potential possibility of harvest (i.e., clear-cut) in the nearest future undermines the effect of the measure (i.e., transition for clear-cut to continuous cover forestry)
		Slope	Forest plots with steeper slopes might require more management costs in continuous cover forestry regime and are more prone to clear-cutting
	Ecologic	Size of transformation plot	Changing management practice in the bigger area will lead to a bigger impact on carbon stability and resilience in the forest property in question as well as neighbouring properties (i.e., spillover effect)
		Planned diversity, minimum three new tree species	Introduction or natural regeneration of less than three new species will have a negligible effect on carbon stability and management practices
		Diversity concentration (planned diversity/size of transformation plot)	Number of new species introduced should be proportionate to the size of transformation plot to have a meaningful ecological effect
		Tree species quality and fitness to climate change	Species that are less common in Styrian forests are encouraged, while they must be suitable for the plot according to the Dynamic Forest typification of Styria (i.e., future climate change).
		Forest plot instability (height/diameter)	Focusing on forest plots with least stability and resilience to weather events will have larger ecologic impact and ensure stability of the carbon cycle in the changing climate
		Spruce must be unnatural	Focusing on forest plots where spruce is unnatural or will become unnatural due to the climate change will have larger

Measure	Criteria type	Criteria	Rational
			ecologic impact and ensure stability of the carbon cycle in the changing climate
	Social	Total size of forest property(ies)	While everyone can participate, forest owners who have higher opportunity costs with less resources to apply for governmental subsidies and other forms of support are prioritized (Engel et al., 2008; Namirembe et al., 2014; Pagiola et al., 2008; Wegner, 2016)

Forest owners could apply for reverse auction from November 2024 until July 2025. An online application form was distributed online and via information events in cooperation with the Styrian Forest owners' association. Interested forest owners were consulted in phone conversations and via e-mail. Overall, 103 applications were received (71 for deadwood/biotope tree and 32 for transforming a forest plot to continuous cover forestry, with 40 and 6 accepted to evaluation, respectively).

Reversing the auctioning procedure also allows for engagement of unlimited funding sources, from crowdfunding to public money and business donations. In our case, Raiffeisen Landesbank Steiermark donated a sum of money sufficient to successfully fund 15 deadwood/biotope tree projects and one spruce-to-continuous-cover transformation plot. Styrian Forest owners' association stepped in as an intermediary between the donor and a winning forest owner. The contracting conditions for each measure is presented in Table 28.

Table 28: Conditions for winners of the reverse auction.

Deadwood and biotope trees	Transformation of secondary spruce monocultures into a continuous cover forestry
The applications must be completed by the forest owners themselves, no third parties may be involved and the content of the application may not be passed on to other forest owners or third parties	
Before the ranking is determined, each winning site will be checked to confirm the validity of the information provided in the application; in the event of misinformation, the applicant will be excluded from the current competition and the next best application will take its place	
The successful forest owner must sign a contract with the Styrian Forest owners' association in which the duration of the implementation and the control and monitoring measures are specified	
The one-off payment is transferred via the Styrian Forest owners' association after the contract is signed	
The winner forest owner must allow access for Styrian Forest owners' association to the forest area where a measure(s) is(are) implemented at any time for controlling, after they receive the payment	
Applicants have the option of withdrawing from the contract at any time, on condition that they repay the full amount, except in cases of force majeure	
Duration of the contract is prescribed by the duration stated in the application, however, shall be no shorter than 20 years	A forest owner applies with a specific forest plot within his forest property and declares his willingness to convert it into a mixed forest with continuous management
Images of the trees can be used by the donors in reporting if the forest owner gives their consent	The forest parcel in question must be a secondary spruce monoculture that is less than 60 years old

Deadwood and biotope trees	Transformation of secondary spruce monocultures into a continuous cover forestry
	Contract duration is 5 years meaning that the transformation must start within this time
	A deadline for the start of the changeover is specified in the contract; if this is not met, the forest owner must give notice and either return the money or set a new date

7.2.2 Tourism Tax (France)

Business model

The integrated business model developed for the Grand Annecy Living Lab is the result of a participatory and iterative design process, combining local stakeholder input with technical and economic projection.

Its purpose is to maintain and enhance forest ecosystem services while creating diversified income streams that sustain the forest owner economy and preserve the tourist recreational service. It aims to allocate a share of the tourism tax that has been in place since 2017 to fund actions that support foresters and forests in coping with the impacts of tourism and outdoor activities in the region. It is also a new way of investing in the forest in the context of climate change.

Two possible solutions have been proposed:

- either by increasing the tax by 2 or 3 cents per tourist overnight stay
- or by allocating a percentage of the current tax between 1% and 2%

The model is built on two complementary pillars:

1. **Active land stewardship and climate-smart forest management:** targeted interventions designed to promote a sustainable forest management in order to adapt the forest to climate change
2. **Development of services: deliver measurable impacts on recreational and landscaping features,** biodiversity issues, and other ecosystem services, potentially monetised through the reallocation of tourist tax and reinvestment mechanisms for landscape maintenance.

Forest Ecosystem Services

The Living Lab concentrates on several ecosystem services:

- Leisure and eco-tourism in the forest,
- Production and supply for the forestry and timber industry,
- Preservation of Alpine biodiversity and related species,
- Protection against natural hazards (avalanches, landslides),
- Protection and preservation of water quality,
- Carbon sequestration and reduction of air pollution.

Options for the development of value chains and the local implementation of business models

The Grand Annecy Living Lab is implementing an integrated business model for Forest Ecosystem Services (FES) through a phased approach, focused on demonstrating early results and scalable impact. Key

strategies involve: prioritizing FES and leveraging innovative monitoring; strengthening stakeholder cooperation and governance; integrating FES into sustainable forest management; utilizing tourism tax for funding; ensuring adaptable, long-term planning for climate change; and transparently communicating outcomes.

Implementation proceeds in three stages: **Short-term (1-2 years):** Establishes foundations, pilots initiatives, and secures initial funding (e.g., tourism tax discussions) through dedicated working groups.

Medium-term (3-6 years): Scales operations by formalizing governance, launching pilot interventions, and refining technical guidelines, primarily funded by the tourism tax.

Long-term (7-15 years): Consolidates actions across forests, diversifies FES markets (e.g., biodiversity), augments funds, and replicates the model regionally, supported by stable tourism tax and robust long-term governance.

7.2.3 Burial forests in Living Lab Endlhausen (Germany)

Business model

The selected business model in the Living Lab Endlhausen is the establishment and operation of a **burial forest ("Kirchlicher Bestattungswald")** at the Buchberg location, operated by the Archdiocese of Munich and Freising ("Erzdiözese München und Freising").

The core service is offering the right to have one's ashes interred in a biodegradable urn at the base of a designated tree within a living forest ecosystem. This model directly addresses the growing societal demand for nature-based, low-maintenance, and spiritually meaningful burial alternatives.

As the operator, the Archdiocese brings a unique value proposition: it combines professional forest stewardship with pastoral care and a mission of preserving creation ("Bewahrung der Schöpfung"). This differentiates it from purely commercial or municipal providers and creates a high level of trust.

Forest Ecosystem Services

The business model mainly focuses on the Aesthetic / spiritual value of nature and is expressed by the FES "Recreation and tourism". The business model makes use of provisioning services (e.g. provision of old trees as burial trees) and conserves other FES, for example maintaining of soil functions and habitats for biodiversity through a reduced and natural forest management.

Options for the development of value chains and the local implementation of business models

During the participation process, several areas of business of interest were identified. After various bilateral consultations, the decision was made in favour of the burial forest. During the decision making process three location alternatives were discussed: The forest at Buchberg and two locations near Sauerlach. The Buchberg area was chosen because it offers the most suitable conditions for establishing a burial forest. The site is characterised by medium-aged to mature mixed forests consisting of spruce, beech, pine, larch, and other species between 101 and 120 years old. The forest also benefits from well-developed infrastructure, including an extensive road network and close proximity to the city of Geretsried. Another topic of debate was whether the forest areas should be leased to a burial forest company or whether the archdiocese should operate the burial forest itself. This point is currently still being discussed internally.

Business model archetype

- Service provider model offering a unique solution with elements of “direct sales” and “customer-funded”, because the customer finances the service
- Given the operator, it also has strong characteristics of a “mission-driven/social enterprise”, where primary goal is fulfilling social/spiritual mission while being sustainable

Good practice examples for business models

- **FriedWald® and RuheForst®:** These are the market-leading commercial providers in Germany. They have strong brand recognition, professional marketing, and standardized processes. They serve as the primary benchmark for pricing and service offerings.
- **Bayerische Staatsforsten (BaySF):** As the state-owned forest enterprise, BaySF is also a significant provider of burial forests in Bavaria, leveraging its extensive forest holdings, established forest management expertise, and regional presence.

7.2.4 Green Initiative in the Living Lab Waakirchen (Germany)

Business model

The selected business model in the German Living Lab “Waakirchen” is the **"Grüne Initiative" (Green Initiative)**, founded by forest owner L.B.. It is conceived as a mission-driven, community-based organization (potentially a registered association - "eingetragener Verein") in cooperation with local clubs and the municipality.

The initiative is built on two core pillars:

1. **Nature Education:** Offering professional, curriculum-aligned nature-pedagogical tours and workshops in the forest. Target groups include schools, kindergartens, families, and tourists. The focus is on creating a tangible connection to the forest ecosystem and promoting understanding of sustainable forest management.
2. **Public Relations & Advocacy ("Lobbying for the Forest"):** Acting as a voice for the forest and its owners. This pillar aims to raise awareness among the public and local policymakers about the forest's multifunctionality and its ecosystem services (carbon sink, water reservoir, biodiversity hotspot, place of recreation) and the challenges forest owners face (climate change, economic pressure).

The unique value proposition lies in the authenticity of the "forest owner's perspective" and the strong local network.

Forest Ecosystem Services

The "Grüne Initiative" explicitly addresses a comprehensive range of Forest Ecosystem Services (FES) across all categories:

- **Cultural FES:** Directly provided through the Nature Education pillar, offering aesthetic appreciation, spiritual values, recreational opportunities, and a strong educational component. Participants gain a deeper understanding and personal connection to the forest.

- **Regulating FES:** The Public Relations & Advocacy pillar explicitly highlights the forest's role as a "carbon sink," "water reservoir," and its contribution to air purification. By raising awareness and advocating for sustainable forest management, the initiative indirectly supports the long-term provision of these vital services.
- **Supporting FES:** The focus on "provision of habitats for wild animals and plants" directly underscores the importance of biodiversity and the underlying ecological processes that sustain the forest ecosystem. Education about these processes enhances public appreciation.
- **Provisioning FES:** While not directly selling timber or non-wood products, the advocacy for "multifunctionality" includes sustainable resource use.

Options for the development of value chains and the local implementation of business models

The Green Initiative model fits primarily into the following archetypes:

- **Mission-Driven / Social Enterprise:** The primary goal is not profit maximization but achieving social and environmental impact (education, awareness, FES protection)
- **Service Provider:** The Nature Education pillar operates as a service provider, offering tailored educational tours and workshops.
- **Community Platform / Network Orchestrator:** Through its cooperation with local clubs and the municipality, and by fostering dialogue between forest owners, the public, and policymakers, the initiative acts as a hub, connecting various stakeholders around a shared interest in the forest.
- **Advocacy / Lobbying Organization:** The second pillar is explicitly dedicated to advocating for the forest and its owners, influencing public opinion and policy decisions.

Good practice examples for business models

- Forest experience centers like Walderlebniszentrum Grünwald near Munich
- Environmental education centers like Umweltstation Würzburg
- Nature parks and biosphere reserves
- Adventure farms and farm pedagogy initiatives
- Local chapter of environmental NGOs with specific projects

7.2.5 Multifunctional Forest Economy for the Tanaro Valley (Italy)

Business model

The business model developed for the Valle Tanaro Living Lab is based on the integration of sustainable forest management, value chain diversification and ecosystem service monetisation. Designed through a participatory process, it combines ecological restoration with local economic development, aiming to make climate- and biodiversity-smart forestry financially viable. The model is structured around **two complementary pillars**:

- **Land stewardship and ecosystem service valorisation**, where targeted forest interventions generate measurable environmental outcomes (carbon sequestration, biodiversity enhancement, landscape quality) certified and monetised through voluntary markets or sponsorships;
- **Development of value-added forest-based products and services**, including timber, non-wood forest products (mushrooms, honey, chestnuts) and experiential tourism, whose revenues directly support forest management activities.

The model functions as a circular system where part of the profits from product sales and tourism experiences is reinvested into restoration, certification and monitoring. It promotes cooperation among municipalities, *Associazioni Fondiarie* (ASFOs), forest consortia, community cooperatives and private companies, creating a territorial alliance for forest stewardship.

Forest Ecosystem Services

The main targeted forest ecosystem services are carbon storage and sequestration, provision of biodiversity, recreation and the provision of Non-Wood Forest Products (NWFPs).

Options for the development of value chains and the local implementation of business models

There are a lot of good practices and opportunities in the area which support the establishment of the business model:

- Local networks (Chestnut orchard networks, forest landowner associations and consortia, green community)
- Energy and green chemistry sector (District heating in Ormea, Tannins value chains)
- Experiences in carbon markets and biodiversity (Small pilos financing bank foundations)
- Slow tourism and non-wooden products (Presence of parks and natura 2000 habitats, valorization of mushrooms and chestnuts)
- Social innovation and inclusion (Community cooperative and *Nuove Radici project*)

The implementation of the business model is structured in three phases, with the progressive alignment of skills, stakeholders and resources. The initial focus will be on demonstrating concrete results, in order to build trust and attract investments.

- **Phase 1: Foundation and testing (year 1-2)**
Initial agreements, pilot testing, branding, certification and launch
- **Phase 2 – Scaling and market penetration (year 3-6)**
Increase of managed surface, product/services development and market activation
- **Phase 3 – Consolidation and innovation (year 7-15)**
Stabilization of the model, long term agreements, innovation

7.2.6 Provision of Wood Biomass (Slovenia)

Business model

BDHS are becoming increasingly common due to the use of renewable and local energy sources—primarily wood biomass—and related incentives. In the Municipality of Tržič, no large-scale municipal BDHS currently exist, although the municipality has extensive forest cover, favourable settlement patterns, and a suitable ownership structure for such systems. Strategic municipal documents, including the Local Energy Concept, already reference renewable energy sources and BDHS. Decisions regarding BDHS implementation are typically gradual and based on municipal strategies related to energy self-sufficiency and the green transition. The establishment of a BDHS would create a new market for lower-quality wood in the municipality, offering potential additional income for forest owners, farmers managing overgrown areas, and companies involved in biomass production and supply. Biomass procurement can be organized either by the municipality or by specialized companies. Agreements with forest owners usually take the form of one- or multi-year contracts, defining prices based on quantity and quality, with possible adjustments for inflation. Greater flexibility from the buyer—allowing smaller delivery volumes or flexible delivery schedules—can attract a wider range of forest owners. Beyond economic benefits (additional income for owners and companies, lower heating costs), BDHS systems increase local energy self-sufficiency, reduce carbon footprints, and promote a circular economy.

Forest Ecosystem Services

The main targeted FES is the provision of Wood Biomass.

Options for the development of value chains and the local implementation of business models

The Tržič Living Lab pursued a comprehensive, phased approach to develop local wood biomass value chains and implement a biomass district heating system (BDHS).

It began by **comprehensively analyzing** municipal biomass potential (using SFS data, WISDOM model, and ownership structures) and demand (municipal plans, local businesses). This was complemented by a thorough review of national legislation (incentives for renewables) and **best practices** from other municipalities regarding BDHS financing, management, and biomass supply chains.

Crucially, the process involved **engaging key local stakeholders**: continuous cooperation with the Municipality supported its Local Energy Concept, and a survey assessed large forest owners' high willingness to supply low-quality wood if a local purchasing system was organized. Interviews with local biomass companies further informed market dynamics.

Awareness-raising activities (local newspaper articles) and a **multi-stakeholder workshop** (including SFS, municipal representatives, forest owners, energy agencies, and best-practice examples) fostered networking, generated ideas, and built consensus for BDHS development.

Future implementation focuses on presenting results regionally, integrating the SFS into energy policies for detailed biomass potential, promoting active and regular forest management among owners, and ensuring continued local cooperation to establish and expand the BDHS long-term. This systematic approach aims to transition from potential to realized BDHS operation, leveraging a well-researched supply chain and strong local buy-in.

7.2.7 Protection against torrents (Slovenia)

Business Model

Our business model is not typical; it is more of a payment scheme. Payment schemes linked to FES provide financial incentives to forest owners and managers to deliver not only timber but also other essential FES. These benefits are achieved through forest protection measures, silvicultural practices, restoration activities, watercourse bank stabilization measures, and higher standards of sustainable forest management, which indirectly increase forest resilience. In the context of managing torrential areas, the state and local communities contribute to public benefits—primarily enhancing the safety of people and their property from the harmful effects of torrential floods—by supporting comprehensive management of these areas. Torrent management encompasses several components, including establishing a monitoring system and service that connects key stakeholders, implementing stabilization and restoration measures, promoting resilient and vital forests within torrential areas, and conducting specific interventions for slope and bank stabilization.

Forest Ecosystem Services

The main targeted FES is the protection against torrents.

Options for the development of value chains and the local implementation of business models

The Tržič Living Lab developed a systematic approach for the **hazard protection FES** through enhanced torrent management, emphasizing collaborative value chain development and local implementation.

Value Chain Development:

- **Knowledge Base & Standardization:** The process commenced with a comprehensive review of legislation and best practices, complemented by specialized employee training (Austrian model). This expertise was leveraged to co-create a tailored torrent inventory and monitoring methodology for Slovenian headwater areas, including field forms and a QField application for standardized data collection and assessment of forest conditions around torrents.
- **Economic Justification:** Preliminary assessments estimated SFS personnel and cost requirements, alongside an analysis comparing flood/erosion damages with preventive forest management costs, underscoring the economic importance of proactive measures.
- **Multi-Stakeholder Collaboration:** The value chain involved extensive cooperation among SFS, research institutions, state forests, private companies, and ministries, ensuring an integrated and informed approach to torrent management.

Local Implementation:

- **Pilot Application:** The developed methodology was rigorously tested and applied in the Municipality of Tržič, with close involvement of local SFS foresters, to identify critical torrents and propose specific forest management and infrastructure interventions.
- **Awareness & Buy-in:** Public and professional awareness-raising activities (articles, workshops, conferences, educational videos) were crucial for fostering local understanding and support for the initiative.
- **Future Systematization:** Long-term implementation focuses on formalizing the torrent inventory system, integrating management guidelines into SFS planning, securing stable financing for preventive measures, updating relevant legislation, and promoting interdisciplinary training and cooperation to embed proactive torrent management permanently into regional practice.

7.2.8 *Recreation and tourism (Slovenia)*

Business model

The Municipality of Tržič offers exceptional opportunities for recreation and tourism, providing potential income for the local community and its residents. Multiple business models for recreation are possible. The first is in the form of payment schemes designed to incentivize forest owners to improve conditions for recreational use within their forests. Other business models can generate additional income for landowners, such as through parking fees, sales of local products, and related services. Indirect benefits are also possible: appropriate measures reduce conflicts and enable regular forest management by owners.

Forest Ecosystem Services

The main targeted FES is recreation.

Options for the development of value chains and the local implementation of business models

The Tržič Living Lab developed value chains for sustainable forest recreation by analyzing visitor behavior and engaging stakeholders. A comprehensive visitor survey (415 responses) provided crucial data on recreational patterns and attitudes.

Value Chain Development Options: The project identified opportunities to develop new services such as structured visitor access (parking, public transport solutions) and proposes controls for mountain forest areas. It also aims to create incentives for forest owners to adapt management for recreation and empower local residents to generate income from tourism. Technical guidelines are being prepared to professionalize recreational use.

Local Implementation: This involved extensive stakeholder workshops (SFS, forest owners, municipality, tourism) to collaboratively identify challenges and propose solutions. Close cooperation with the Municipality of Tržič facilitated data collection, communication, and event organization. Public and professional awareness campaigns (media, educational videos) built support. Future activities include presenting these models, formalizing visitor access solutions with the municipality, and continuing collaboration with local communities to ensure long-term, adaptive management of recreational FES.

7.3 Conclusions for the Alpine area

7.3.1 Opportunities

Fostering and encouragement of forest ecosystem services

In the previous chapters the value chain development in the five living lab areas has been presented. The exchange with stakeholder about new value chains in the living labs revealed different opportunities how individually tailored, site-specific business models can be developed which support the maintenance of forest ecosystem services (cf. Table 29).

Table 29: Coverage of forest ecosystem services by proposed business models

Main forest ecosystem services	Timber biomass provision	Fire-wood biomass	Natural hazard prevention	Carbon sequestration	Biodiversity & Habitat provision	Water regulation	Recreation	Aesthetic & spiritual services
Business model								
Reverse Auction (AT)				x	x			
Tourism Tax (FR)	x		x	x	x	x	x	
Burial Forest (DE)					x		x	x
Green Initiative (DE)				x	x		x	x
Multifunctional Forest Economy (IT)				x			x	
Provision of wood biomass (SI)	x	x						
Protection against torrents (SI)			x					
Recreation & tourism (SI)							x	

The table shows that each business model can cover at least one, often multiple ecosystem services. This means, that each business model can contribute to an increase of social value of the forests according to the values presented in chapter 4.4. These interlinkages can be enriched in future by adding good practice examples and offer opportunities for forest owners, what they might do with their forests.

Identification and development of business models

There is a much broader portfolio of business options available for forest owners as timber production. A diversification of the “product portfolio” of forest owners may offer economic stability and resilience. The opportunity is to widen the perspective and develop a broader business portfolio. This could be also an

option of sharing portfolio components within owner associations. Such as different owners in a geographic neighbourhood offer different business components and share revenues.

If read from the ecosystem service columns, the Table 29 would also allow to look for suitable business models, which can foster specific forest ecosystem services.

Stakeholder involvement and governance development

The participative approach in the living labs certainly offers closer contact to stakeholder and decision maker for a longer time period. It offers the side effect that interaction between different, and sometimes unknown, stakeholder new decision processes and governance styles are developed.

7.3.2 Challenges

Certainly, the business model approaches and development processes include also challenges, which are briefly listed below.

Knowledge, ecosystem service data and assessment

The framework for developing business models based on forest ecosystem services require certain knowledge, the access to appropriate forest data and the capability to perform an assessment. This may be a challenge, if people are completely new to this field. A starting point can be the guideline, which was developed in course of this project, the support of forest experts.

Climate change effects

Forests in the Alpine area will undergo severe changes of their environmental conditions due to climate change, and by this they are affected by related challenges. Again here, the “inactivity option” may be the most vulnerable and risky one.

Business model selection and development

The selection of an appropriate, site-specific and successful business model and its development contain the general enterprise’s risk. However, the business diversification may also be an opportunity at the same time.

Investments in the participation process

The process to develop new business ideas and involving relevant stakeholder is consuming time and energy, which may challenge those being the entrepreneurs in this field.

8 Conclusion for transnational collaboration with institutions

In this chapter we draw some conclusions how the approach and the results of the ForestEcoValue project might support the collaboration and the objectives of selected transnational institutions in the Alpine area.

We have selected institutions which could support also a transnational collaboration supporting the maintenance of mountain forests and sustainable value chains for them. In the subchapters we will address selected main objectives of the institution, potential support of the ForestEcoValue approach and some indications for opportunities of the institution's objectives.

The institutions addressed are:

- Alpine Convention Working Group Mountain Forest and Agriculture
- Alpine Convention Alpine Climate Board
- Alpine Convention Alpine Biodiversity Board
- EUSALP AG 6 Resources
- EUSALP AG 7 Green infrastructure
- EUSALP AG8 Risk Governance

8.1 Alpine Convention Thematic Working bodies

8.1.1 Working group Mountain Forest and Agriculture

Selected main objectives of the institution

Main objectives of the WG Mountain Forests and Agriculture in its mandate 2023-2024 are:

- Objective 2: Understanding of new opportunities for mountain territories in terms of ... forestry productions and management approaches that favour or are already in line with ecological transitions and circular economies.
- Objective 4: ... forest activities targeting a good balance of innovations and traditional practices, an efficient use of inputs and favouring reduction of greenhouse gases emissions or increase in GHG sink.

Potential support of the ForestEcoValue approach

The ecosystem service-based approach of ForestEcoValue offers to consider of ecosystem relevant effects of forestry, such as greenhouse gas emissions or CO₂ sequestration.

The business models collected and tested in ForestEcoValue may serve as examples for "new opportunities" for forestry production and management approaches.

Opportunities for the institution's objectives

The WG Mountain Forest and Agriculture might promote in projects the use of ecosystem services and their monitoring to ensure greenhouse gas emission reduction and CO₂ sequestration. Furthermore they might advise forest owners and practitioners to widen their portfolio and take further business models on board which increase CO₂ sequestration.

8.1.2 Alpine Climate Board

Selected main objectives of the institution

Main objectives of the Alpine Climate Board (ACB) are:

- In the mandate 2025-2026 topic No. 3: Cross-cutting topic “Nature-based solutions (NbS)”: the ACB seeks to further work towards an Alpine-wide implementation of nature-based solutions and identify common areas of action while assessing their role and effectiveness for climate and biodiversity protection and climate adaptation.
- The Climate Action Plan 2.0 of the Alpine Convention identified four implementation pathways for mountain forests:
 - IP-Fo1: Promoting the full use of the potential of Alpine protective mountain forests,
 - IP-Fo2: Promoting Alpine forests as carbon sinks,
 - IP-Fo3: Accelerate forest conversion to more resilient & close-to-nature ecosystems
 - IP-Fo4: Promote an Alpine-wide integrated sustainable forest management approach
- Among other, this includes the following steps:
 - to testing financial incentive schemes in pilot areas to provide financial support for resilient forestry throughout the Alps,
 - to implement regional value added chains of wood in the Alpine regions.

Potential support of the ForestEcoValue approach

Forest ecosystems offer many nature-based solutions, such as natural-hazard protection against rockfall, mudslides, avalanches, floods, the protect groundwater quality and are important interceptors or rainfall. Forest also are important sinks for carbon and provide air purification in the surrounding of settlements.

The identification of forest ecosystem services is an excellent foundation for the development of forest related nature-based solutions.

The Forest EcoValue project joins the analysis of forest ecosystem services and an approach to develop tailored business models for a broader economic basis.

Opportunities for the institution’s objectives

Business models and good practices compiled in Forest EcoValue as well the approach of developing business models on basis of ecosystem services can support the implementation steps of the Climate Action Plan.

Natural hazard prevention is one of the ecosystem services the project has dealt with. The economic assessment has revealed, that this forest ecosystem service represents one with the highest social relevance and economic unit values, supporting IP-Fo1.

Carbon sequestration is another ecosystem service of forests which was assessed and for which also high social relevance and economic value was calculated, which supports IP-Fo2.

Close-to-nature forests (IP-Fo3) will offer higher recreational and aesthetic values, two forest ecosystem services which were also analysed and tackled in the living lab process.

The implementation pathway IP-Fo4 is supported by the overall objective of the project to develop sustainable forest management approaches to maintain and improve forest ecosystem services.

8.1.3 Alpine Biodiversity Board

Selected main objectives of the institution

Main objectives of the Alpine Biodiversity Board in its mandate 2025-2026 are:

- Topic 2: Restoration: Restore the ecological functionality within the Alps. Ecosystem restoration is considered an essential element in the recovery and conservation of biodiversity. For this reason workshops with public actors EUSALP AG 7 are envisaged to foster strategic exchange between Alpine countries on national restoration plans ... with a specific focus on topics with high relevance at the Alpine level like ... forests.
- Topic 4: Conservation: Improve status of conservation for priority species and habitats. The network of protected areas in the Alps should be improved, both in terms of the level of protection and the territorial coverage of the network, to provide effective protection for taxa which need specific conservation efforts. To formalise and implement concrete conservation actions at the Alpine level, priorities need to be defined first. In particular, certain ecosystems should be highlighted for their contribution to ecosystem services in the Alps and beyond.

Potential support by the ForestEcoValue approach

The ForestEcoValue approach can support the restoration and maintenance of forests mentioned in topic 2 as highly relevant ecosystems. Thus, activities can be supported by systematically linking ecosystems and their ecosystem services with sustainable business models. Often the lack of appropriate business models is a reason for abandoning land uses of areas with high biodiversity values. This gap can be closed by the Forest EcoValue approach and its options to transfer it to different ecosystems and business models.

Also, topic 4 might be supported by ForestEcoValue as ecosystem services of forests are explicitly elaborated for different forest types in the five living lab areas. The systematic methodology to identify and measure ecosystem services using appropriate biophysical indicators may support the level of protection of Alpine forests.

Opportunities for the institution's objectives

Forests are explicitly mentioned in topic 2 as highly relevant ecosystems. The maintenance of forest ecosystem services means also the restoration of forests and their ecological functions. Business models for forest owners beyond timber production offer the economic basis for achieving topic 2.

The ForestEcoValue approach could be used by the ABB to identify forests with high ecosystem service provision and use this for an evaluation and revision of protected forests, but at the same time to define the framework for a sustainable forestry.

8.2 EUSALP Action groups

8.2.1 Action Group 6 Resources

Selected main objectives of the institution

Main objectives of EUSALP AG 6 Resources are:

- The EUSALP AG 6 states its core mission as “to preserve and valorise natural resources, including water and cultural resources in the Alpine Region. AG6 aims to provide valuable contributions to an Alpine strategic framework that allows the establishment of sustainable and balanced models of resource management and production.”
- The flagship initiative of EUSALP AG6 is the coordination of and contribution to the activities of the Task force Multifunctional Forests and Sustainable Use of Timber (TF-MFSUT).

Potential support by the Forest EcoValue approach

The approach of the project offers a balanced and innovative model for forest resource management and production as indicated in the mission statement of EUSALP AG 6. The project’s approach can maintain forests as natural resources and as a basis for different production processes.

Opportunities for the institution’s objectives

The Forest EcoValue project is directly mentioned in the specific objectives of the AG 6 and therefore represents itself a support for EUSALP AG 6.

The multifunctionality of forests is well demonstrated by the different ecosystem services which have been analysed and assessed in the Forest EcoValue project. The approach can be used to document the multifunctionality of forests and can be disseminated as well as good practices from the Forest EcoValue project may be used within the Task Force MFSUT.

8.2.2 Action Group 7 Green Infrastructure

Selected main objectives of the institution

Main objectives of EUSALP AG 7 “Green Infrastructure” are:

- Mission: For developing a strategically planned network of natural and semi-natural areas, including features in rural and urban areas which together – functionally interconnected – ensure diverse advantages for nature, as well as social benefits and economic prosperity for humans.
- Specific objective: To identify Alpine GI elements of transnational relevance, improve governance approaches and explore funding opportunities.
- Specific objective: To allow the benefits of ecological connectivity to emerge at ecosystem and societal dimensions, enhancing resilience to threats such as climate change.

Potential support by the ForestEcoValue approach

Generally spoken, forests in the Alpine area are an important pillar of green infrastructure in the Alpine area. Other than agricultural land use, human interventions in forests are in most cases less disturbing, as forest measures are carried out less frequently compared to agricultural measures. Forests are used by many species as semi-natural areas for protection, retreat, and migrating through the cultural landscapes of the Alps.

The Forest EcoValue project has explored different dimensions how forests provide ecosystem services which finally contribute to human well-being and economic prosperity and what social value they

represent. Such ecosystem services are relevant not in forests but also for surrounding rural and neighbouring urban areas. Therefore, and as forest are middle- to long-term land uses forest represent an important part of a strategic network as envisaged by EUSALP AG 7.

Often forests are stretching across national borders and therefore represent a green infrastructure of transnational relevance. Forests are, together with soil management, one of the major responses to climate change.

Opportunities for the institution's objectives

The EUSALP AG 7 may take advantage from the Forest EcoValue project in collecting additional rationales for maintaining or improving the status of forests which are part of green infrastructures. These rationales include the relevance of ecosystem bundles provided by forests, which underline the multi-functionality of forests, the contribution of these ecosystem services for human well-being as presented through the biophysical assessment, the economic relevance of forest ecosystem services as presented in the social valuation and finally the perspective to offer new value-chains for forest services which support forest management in mountain areas.

EUSALP AG7 could use the forest ecosystem service approach to analyse particularly the multi-functionality, ecosystem services, their social values and potential business models for trans-border forests.

8.2.3 Action Group 8 Risk Governance

Selected main objectives of the institution

Main objectives of EUSALP AG 8 “Risk Governance” are:

- The overall objective of Action Group (AG) 8 is to improve and enhance risk management, including the prevention of risks from natural hazards, and climate change adaptation in the Alpine region.
- Specific objective: 2. Improving risk and adaptation governance mechanisms in the EUSALP region by enhancing, valorizing and leveraging the existing cooperation structures.

Potential support by the Forest EcoValue approach

Natural hazard prevention is an important ecosystem service which proved to represent one of the highest ranked social values. Natural hazard prevention has been tackled in the Forest EcoValue project in terms of rockfalls, floods and torrents. Thus the project may contribute to the overall objective.

Governance mechanisms have been considered in the Forest EcoValue approach via the Living lab exercises, in which stakeholder from different fields shared their opinion on the assessment of ecosystem services and the common development of business models. This participation process included stakeholder analysis and common experiences about mutual dependencies and can serve as a wealth of experiences for governance mechanisms.

Opportunities for the institution's objectives

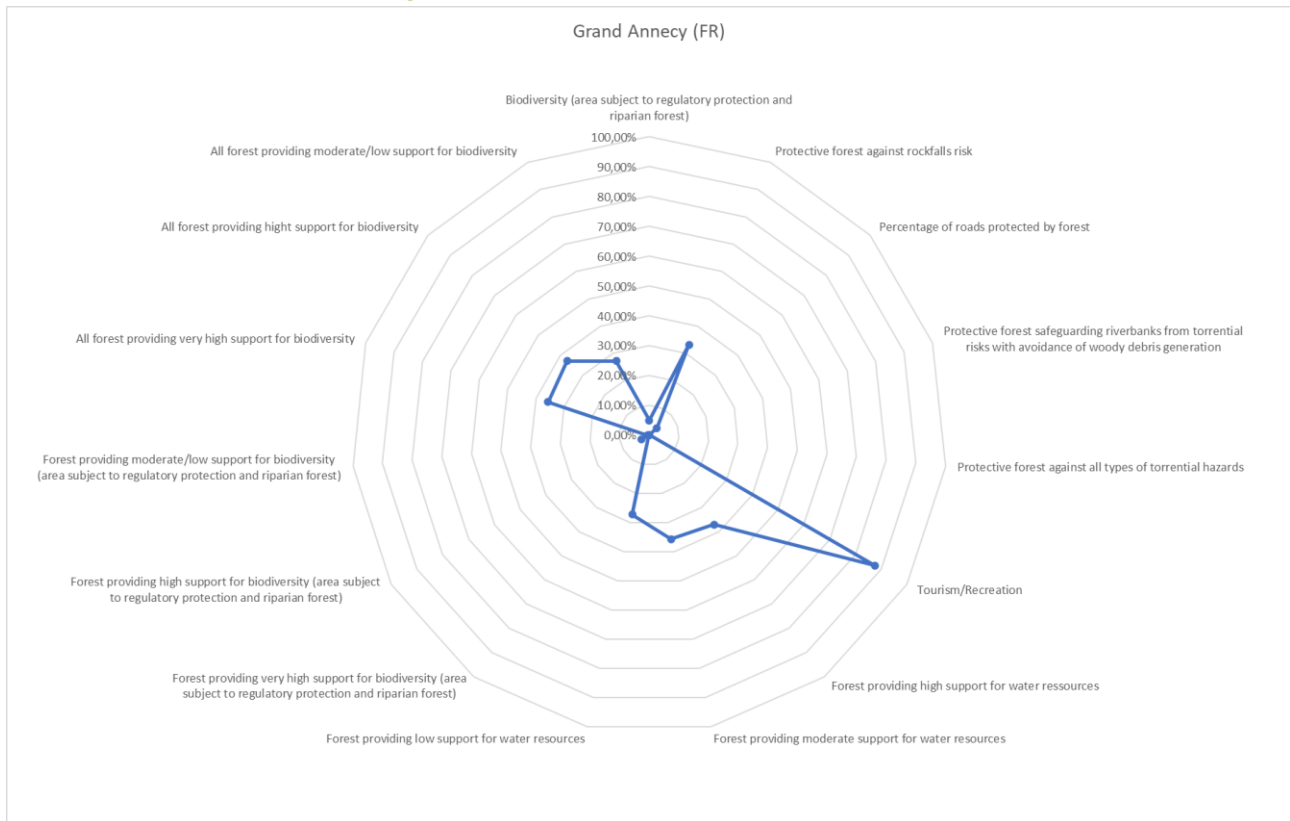
The overall objective of EUSALP AG8, improving and enhancing risk management in an economic way by using ecosystem services of mountain forests and flood plain forest to regulate natural hazards. These nature-based solutions offer at the same time climate change adaptation effects, such as higher frequency of weather extremes, high and sudden run-off events, soil erosion but also drought effects.

The specific objective 2 of EUSALP AG8 can use experiences of the participation process in the Forest EcoValue living labs demonstrates how existing cooperation structures can be enhanced or new cooperation structures can be developed in elaborating innovative business models.

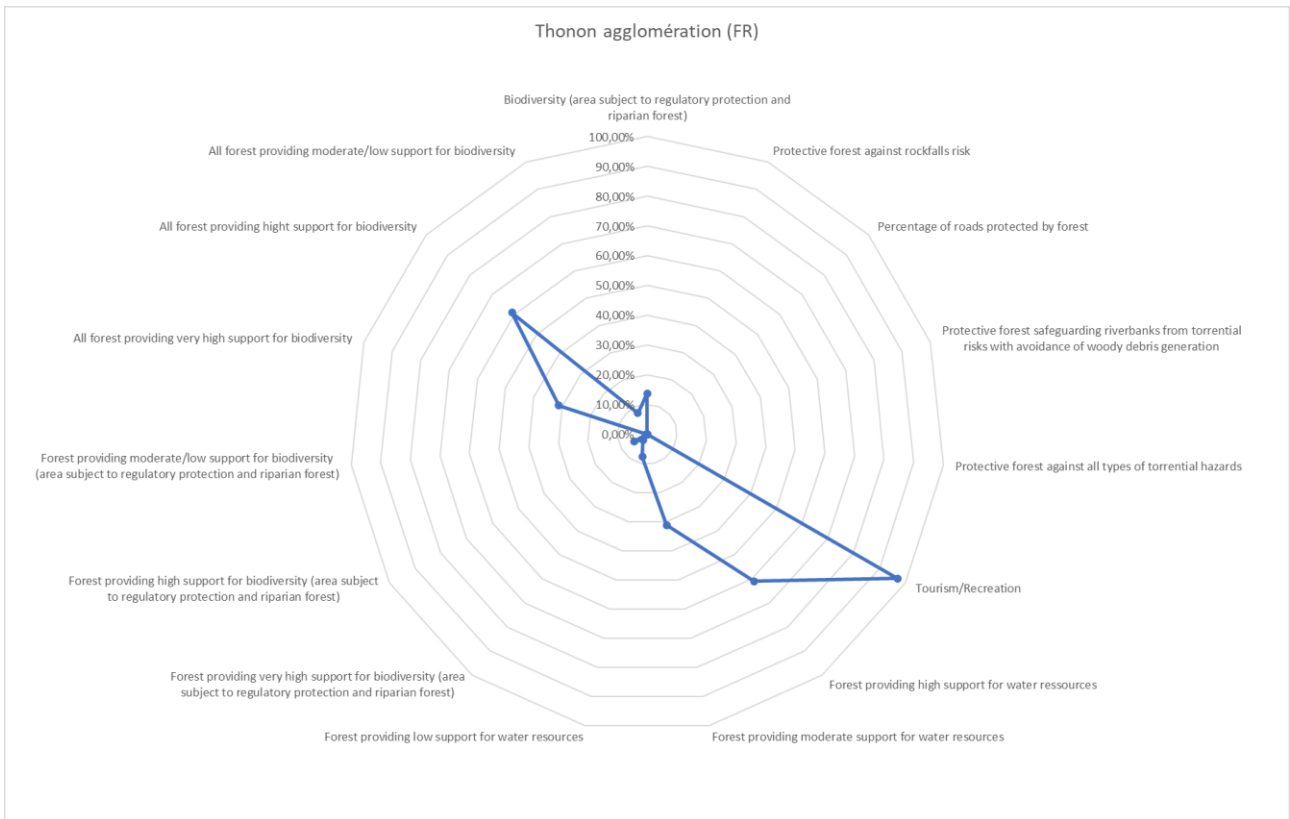
10 Annex: Forest ecosystem service check card

In this annex a “forest ecosystem service check card” is presented which was developed by PP INRAE. The graphs compile, based on the forest area, for each pilot area the different percentages of the forest area, which contribute to different forest ecosystem services.

10.1 France Grand Annecy



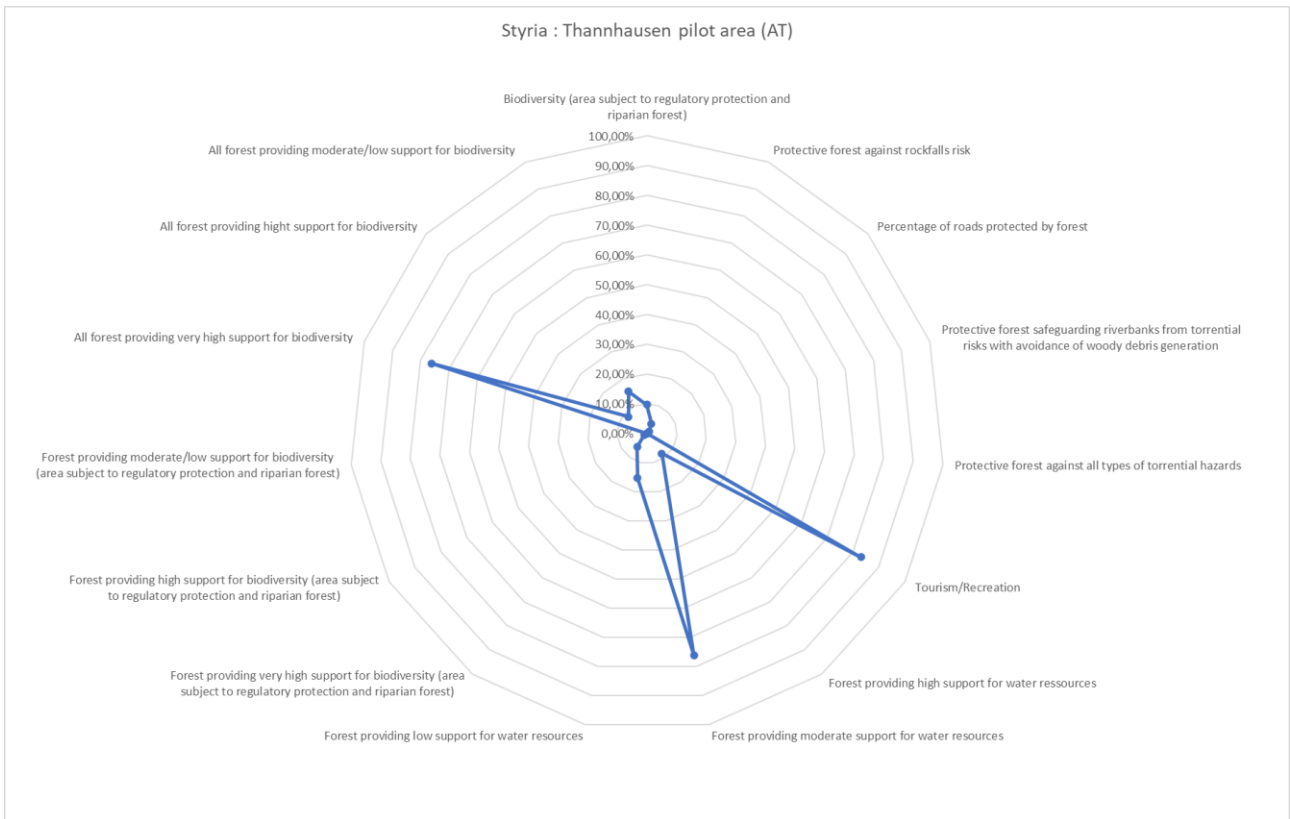
10.2 France Thonon



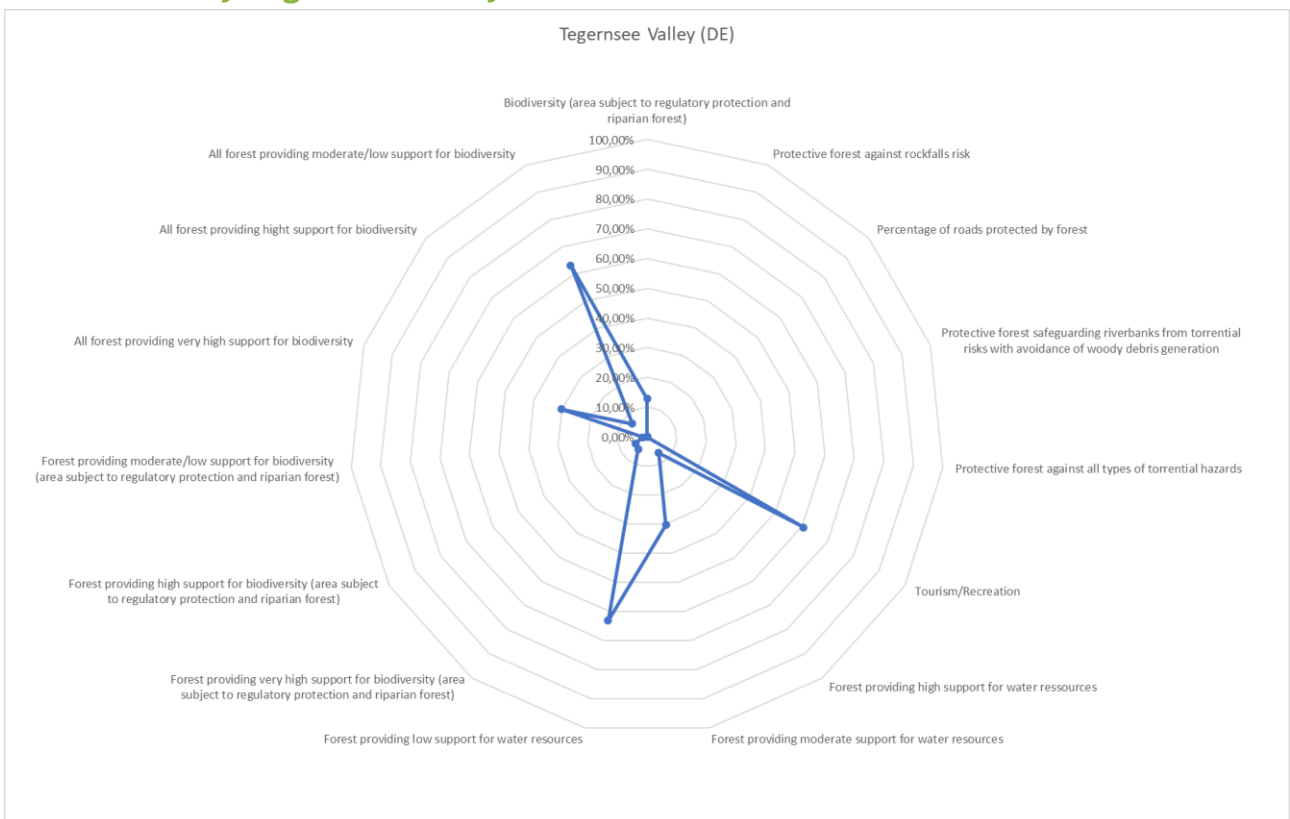
10.3 Italy Tanaro Valley



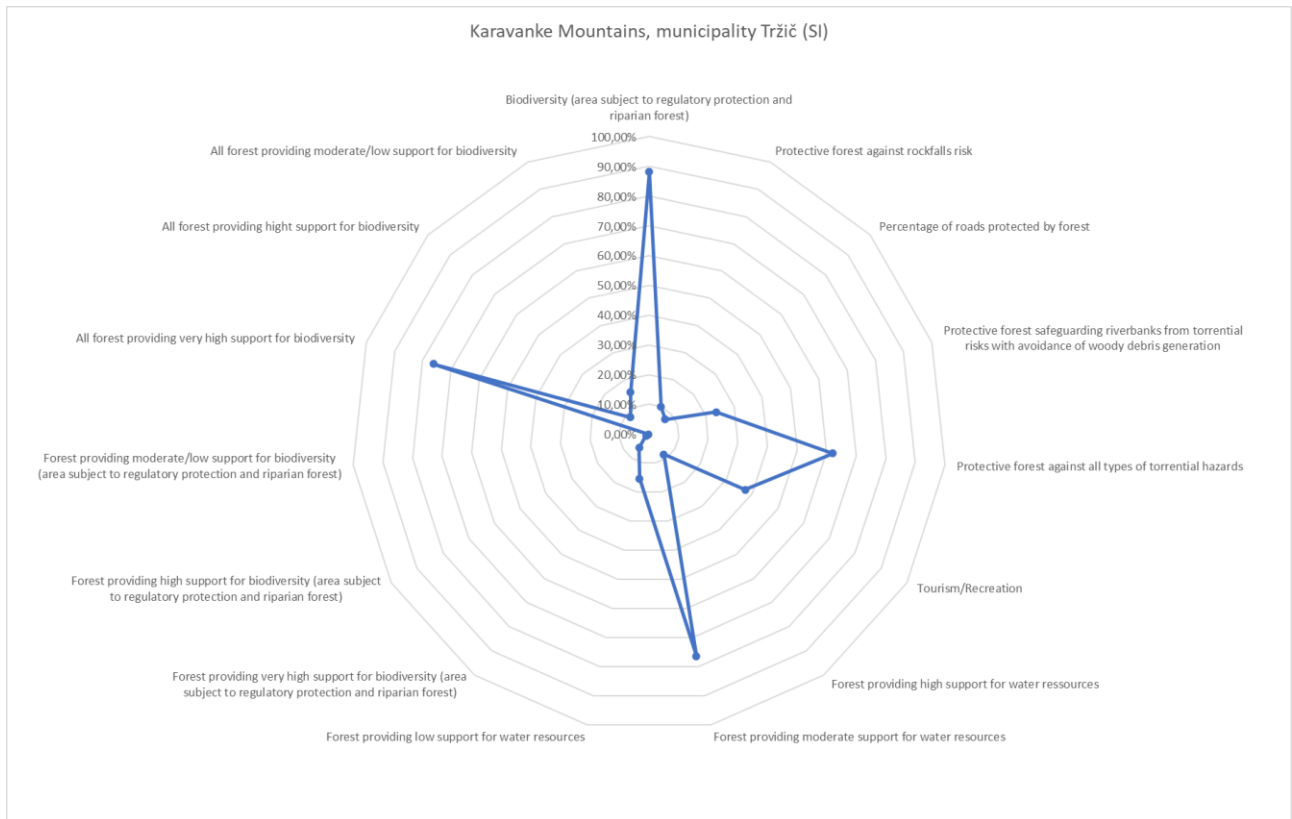
10.4 Austria Thannhausen



10.5 Germany Tegernsee Valley



10.6 Slovenia Trzic



9 Annex: Local scale indicator factsheets

In this annex the local scale indicator factsheets are presented which were developed by PP6 ifuplan.

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Alpine Space

Forest EcoValue

Forest EcoValue

Promotion of diverse ecosystem services of the mountain forest through new circular/green/organic markets and value chains

Indicator factsheet on the ecosystem service Habitat Provision

Leo Krogmann

PP6 ifuplan

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1 Definition and background of ecosystem services

Title of the ecosystem service

Provision of habitats for wild plants and animals that can be useful for us

1.1 Definition of ecosystem services

Brief description of the ecosystem service

The quality of the habitat provision results from the consideration of numerous factors, e.g. species diversity, protection status of the area, composition and age of the tree population. These parameters provide information on the condition of a habitat.

The higher the habitat quality, the more suitable the area is as a habitat for flora and fauna. If there is a high level of human influence on the area through forestry operations, the area will have low habitat quality values. If, on the other hand, the area is very natural and undisturbed, the values are high. This means that there is competition between this ecosystem service and others. For example, conflicts of interest can arise between timber extraction (provision of wood biomass) and habitat provision, as human intervention can have a strong negative impact on habitat quality for animal and plant species.

Classification within the CICES system

Section:	Regulate and Maintenance
Division:	Regulation of physical, chemical, biological conditions
Group:	Lifecycle maintenance, habitat and gene pool protection
Class:	Conservation of breeding populations and habitats
Class type:	By sum and source
CICES code:	2.2.2.3

1.2 Background information on ecosystem services

All day relevance in the living lab area

Habitat provision is highly relevant for the living lab, as a diverse habitat ensures the stability of the entire ecosystem. The more diverse a habitat is, the less susceptible it is to influences such as extreme weather or disease. A stable habitat is therefore also a resilient provider of other ecosystem services.

Information to status of the relevant ES in the living lab area

Habitat provision in the pilot region is for the most part rather low and is mostly at a value of 3 or below, which speaks in favour of medium to low habitat quality. Only the area in the Tegernsee mountains has

larger areas with values of 4 and 5, which indicate habitat provision with high habitat quality. In the four other areas, such high values occur only sporadically, if at all.

Political relevance at EU / national level

The conservation and promotion of species-rich habitats and biodiversity play an important role in policy. Examples of this at EU level include the Biodiversity Strategy 2030, which aims to restore degraded ecosystems, and at national level the “Bundesnaturschutzgesetz” (Federal Nature Conservation Act), which sets out binding regulations for the protection of habitats and species. At regional level, for example, the Bavarian species and biotope protection programme records the areas and species occurrences relevant to nature conservation on the basis of **biotope and species protection mapping**. These results can be used to derive objectives and proposed measures for the conservation and improvement of habitat provision.

1.3 List of possible indicators for ecosystem services

Ecosystem service	Indicator-type*	Indicator	Indicator unit	Description
Habitat provision	Supply	Age of the trees	%	Proportion of old trees or legally protected biotopes in the area
		Biotope density	%	

* There are also indicators for the “demand” (how high is the demand for this ecosystem service?), the “flow” (how much of the ecosystem service provided is utilised) or the “potential” (how high would the natural provision of the ecosystem service be?). In the Forest EcoValue project, we are focussing on supply indicators.

2 Selected indicator for ecosystem services

Mapping of protected species and habitats by the “Bayerischen Landesamt für Umwelt” (Bavarian State Office for the Environment), which includes the above-mentioned indicators.

2.1 Brief description of the selected indicator

Definition

Bewertung der aktuellen Lebensraumfunktion hinsichtlich des Vorkommens von Pflanzen- Tierarten

Interpretation of the indicator

The protected asset map allows far-reaching conclusions to be drawn about the quality of habitat provision, as it brings together a large number of assessment criteria.

Justification for the selection of the indicator

The indicator was selected because it represents a free data basis that can be used throughout Bavaria and is therefore easily transferable.

Political significance

The indicator can provide information for political measures, as it identifies forest areas with high habitat provision and areas with optimisation potential, which can form the basis for planning measures or developing alternative business areas.

2.2 Data sources and documentation of the indicator calculation

Data availability at the level of the Alpine Space cooperation area

The availability of data at national or transnational level is unclear. If there is no corresponding aggregated map of protected assets for the national or respective partner countries, this can be produced using the data below, for example.

Data availability at the pilot area level

The following data is available at the pilot area level:

- Species conservation mapping
- Biotope mapping
- Protected area boundaries
- Forest management data of forest owners
- ALKIS Actual utilisation (*ALKIS Tatsächliche Nutzung*)

Steps for calculating the indicators for mapping

The basis for the inventory map of the ecosystem service “habitat provision” is the Bavarian State Office for the Environment's Bavaria-wide “Species and Habitats” protected asset map, in which the habitat functions are assessed with regard to the occurrence of plant and animal species and their habitats.

The most important assessment criteria are the “Species and Habitats” protected asset map (LfU 2025):

- existing protected area classifications (nature conservation areas, Natura 2000, natural forest reserves)
- Hemeroby (utilisation type and location, e.g. grassland on moorland, zonal coniferous forests)
- Valuable areas substantiated by technical bases, e.g. ABSP areas, areas of species conservation mapping (from 1990), mapped biotopes and areas with high biotope density (distribution and size of near-natural habitats)

The assessment procedure follows a hierarchically graded decision cascade:

- The highest value level (5 - predominantly very high) includes areas whose value is documented by a legal protection status (protected areas, Natura 2000).
- The value level “4 - predominantly high” includes areas whose value can be verified by specialised mapping.
- The other value levels (3 - predominantly medium, 2 - predominantly low and 1 - predominantly very low) are interpretations of the above-mentioned assessment criteria based on the utilisation types.

In accordance with the target scale of the protected assets map (1:25,000 to 1:100,000) and the quality of the bases used, all value levels are labelled with the addition “predominantly”. This means that high-quality habitats can also occur in parts of the landscape in value categories 1 to 3 that could not be recorded with the bases used. This is more likely to occur in landscapes characterised by grassland and in forests in general, where the data situation is often inadequate due to the lack of biotope mapping, among other things.

The information from the above-mentioned map of protected assets was transferred to the study areas from the living lab (using the Clip geo-tool).

In the next step, all stands older than 100 years were selected from the forest management data of the forest owners. These were intersected with the protected property map (using the Union geo-tool) and the resulting areas were assigned the highest value level 5 from the protected property map, as old trees represent a high habitat potential (Bernatzky 1979).

In the final step, the deciduous forest areas were selected from the Copernicus High Resolution Layer “Forest type” and converted into polygons. These were intersected with the previously created data (using the Union geo tool). Finally, all deciduous forest areas were upgraded by one value level using field calculation (using the field calculation geo tool), as deciduous forest stands have an increased deciduous forest potential (Welle et al. 2018).

3 References

Bernatzky, A. (1979): Funktionswert einer 100jährigen freistehenden Buche bei besten ökologischen Voraussetzungen (Baum-Zeitung, 13).

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Alpine Space

Forest EcoValue

Forest EcoValue

Promotion of diverse ecosystem services of the mountain forest through new circular/green/organic markets and value chains

Indicator factsheet on the ecosystem service Carbon storage

*Andrea Emmer
PP6 ifuplan*

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1 Definition and background of ecosystem services

Title of the ecosystem service

Carbon storage

1.1 Definition of ecosystem services

Brief description of the ecosystem service

The ecosystem service describes the ability of forests to absorb carbon dioxide (CO₂) from the atmosphere and bind it in the long term. This happens through the process of photosynthesis, in which trees absorb CO₂ and store it in the form of carbon in wood, leaves and roots. In the following, above-ground and below-ground carbon storage is taken into account.

Classification within the CICES system

Section : Regulation

Division: Physical, chemical and biological regulation

Group: Atmospheric composition and conditions

Class: Regulation of the chemical composition of the atmosphere and oceans

Class type: By the contribution of a particular habitat to quantity, concentration or a climatic parameter

CICES-Code: 2.2.6.1

1.2 Background information on ecosystem services

All day relevance in the living lab area

Carbon storage has daily relevance in the living lab. Trees continuously absorb CO₂ from the air during photosynthesis (during the day), regulate the microclimate and contribute to mitigating the greenhouse effect. This stabilises the climate in the long term.

Information to status of the relevant ES in the living lab area

The ecosystem performance depends on the amount of living wood biomass in the living lab.

Political relevance at EU / national level

Ecosystem services have a high political relevance at national and international level and play a central role in national and international climate protection, environmental policy and the international climate agreement. Ecosystem services also play a major role in emissions trading and CO₂ pricing, as well as in land use and development policy, agriculture and nature conservation.

1.3 List of possible indicators for ecosystem services

Ecosystem service	Indicator-type*	Indicator	Indicator unit	Description
Carbon storage	Supply	Tonne C per hectare	t C / ha	The indicator describes the amount of carbon (C) that is stored or sequestered above and below ground per hectare (ha).

* There are also indicators for the “demand” (how high is the demand for this ecosystem service?), the “flow” (how much of the ecosystem service provided is utilised) or the “potential” (how high would the natural provision of the ecosystem service be?). In the Forest EcoValue project, we are focussing on supply indicators.

2 Selected indicator for ecosystem services

The indicator best suited to describe the forest ecosystem service carbon storage is

Ton of carbon per hectare (t C / ha)

2.1 Brief description of the selected indicator

Definition

The indicator t C/ha describes the amount of carbon (C) that is stored or sequestered per hectare (ha). For the calculation, the living, above-ground and below-ground quantity of carbon is taken into account.

This is made up of all above-ground and below-ground lignified parts of the trees (roots, trunk, branches and twigs). The below-ground biomass of the roots is approx. 20 percent of the above-ground biomass and is taken into account by multiplying it by an expansion factor.

Interpretation of the indicator

This indicator shows how much carbon a particular type of forest or vegetation stores per hectare per year. A high value means that the ecosystem binds a lot of C, while a low value indicates lower C storage.

Justification for the selection of the indicator

The indicator is easy to understand and widely accepted.

Political significance

The indicator provides important information in the areas of climate protection, land use and forestry. Governments can use it to assess how effectively ecosystems store carbon. The indicator also serves as a basis for reforestation programmes and compliance with national and international climate targets (e.g. Paris Climate Agreement, EU climate policy), the promotion of REDD+ (Reducing Emissions from Deforestation and Forest Degradation), CO₂ pricing and emissions trading.

2.2 Data sources and documentation of the indicator calculation

Data availability at the level of the Alpine Space cooperation area

Data availability at the level of the Alpine region is not known.

Data availability at the pilot area level

The following data is available for the forest areas of the Archdiocese of Munich-Freising at local and national level:

- Digital forest establishment data from the years 2016 to 2018 in shape format, including information on tree species proportions, age spread, utilisation type, degree of stocking, harvesting stock in harvestable cubic metre (Efm) of derb wood without bark (D. o. R.) per ha for the years 2016 to 2018, etc.
- Information on average annual increments in $m^3/ha \cdot a$ by tree species and average cutting rates in Efm/ha $\cdot a$ by tree species from the fourth National Forest Inventory 2022

The following data is available for the forest areas near Waakirchen:

- Digital terrain model in raster format (grid size 1.0 m)
- Digital surface model in raster format (grid size 0.8 m)
- Information on deciduous and coniferous wood from the High Resolution Layer Forest Types (Copernicus 2018) in raster format (grid size 10 m)
- Analogue economic map/forest management map (status: 2016) of the forest owner with information on the divisions, subdivisions and the age classes of the respective subdivisions. This has been digitised and is available in shape format.
- Parcel map of the forest owner in Esri shape format
- Auxiliary forestry tables for estimating harvest stocks D.o.R. in Efm/ha according to Assmann & Franz (1963): Spruce, preliminary yield table, average yield level

The indicator is presented on a portfolio basis.

Steps for calculating the indicators for mapping

1.) Calculation of the wood biomass in cubic metre of stock (Vfm) per ha from the absolute wood stock in Efm D. o. R. /ha by multiplying by a factor of 1.2 (see also: Indicator factsheet on the provision of wood biomass)

2.) Application of the IPCC equation to calculate t C/ha:

The most common measure of wood supply is the cubic metre of stock (Vfm), which is the measured or estimated standing timber volume of a tree or forest stand up to a diameter of 7 cm. In order to calculate the total above-ground and below-ground biomass from the cubic metre of solid wood, a so-called expansion factor of 1.4 can be roughly applied. The stored carbon mass can then be calculated using the density of the wood and the carbon content:

$$\text{Biomass storage in t C} = \text{Amount of wood in Vfm} * \text{Expansion factor in fm/Vfm} * \text{Volume density of wood in t/fm} * \text{Carbon content in tC/t}$$

- Amount of wood: Volume of wood in cubic metre (fm)

- *Expansion factor: factor 1.4 for converting stock cubic metres (Vfm) into total biomass above and below ground (fm)*
- *Volume density: density of the wood in tonnes per solid cubic metre; the volume densities differ depending on the tree species, here an average value of 0.494 from all tree species, derived from Klein & Schulz (2012), was used*
- *Carbon content: the proportion of carbon in the total wood biomass in tC/t; the proportion is constant across all tree species at 0.5*

Formula in GIS: $[bio_total]*0.5*1.4*0.494*1.2$

3 References

Klein, D. & Schulz, C. (2012): *Die Kohlenstoffbilanz der Bayerischen Forst- und Holzwirtschaft. Abschlussbericht 09/2012. Ed. by Bayerische Landesanstalt für Wald und Forstwirtschaft (LWF).*

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Promotion of diverse ecosystem services of the mountain forest through new circular/green/organic markets and value chains

Indicator factsheet for forest ecosystem services Provision of wood biomass

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1 Definition and background of ecosystem services

Title of the ecosystem service

Provision of wood biomass

1.1 Definition of ecosystem services

Brief description of the ecosystem service

The production output of the forest is primarily determined by the provision of wood as a raw material. In order to meet the demand for the versatile raw material wood, a corresponding amount of timber is harvested. Sustainable timber production and utilisation ensures that the amount of timber harvested does not exceed the annual growth. This ensures a constant supply of the raw material.

The wood obtained during felling can be categorised as stem wood, energy wood, industrial wood and non-utilisable wood. According to the fourth Federal Forest Inventory 2022, around 52% stem wood, 37% energy wood, 7% industrial wood and 4% non-utilisable wood was harvested in Bavaria (LWF 2025).

The ability of the forest to produce wood, and thus the availability of the renewable raw material, is significantly influenced by the management method, environmental factors and species composition.

Classification within the CICES system

Section:	Provision	
Division:	Biomass	
Group:	Cultivated plants for food, as a source of material or energy	
Class:	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic material)	Cultivated plants (including fungi, algae) grown for energy production
Class type:	Material by quantity, type, use, medium (land, soil, freshwater, sea)	By amount, type, source
CICES codes:	1.1.1.2	1.1.1.3

1.2 Background information on ecosystem services

All day relevance in the living lab area

Wood is a material that can be found in almost all Alpine communities and is a well-known and universally utilised material for building, construction, furniture and insulation. Wood is also an important renewable raw material for energy use. The availability of wood is therefore important throughout the Alpine region.

Information to status of the relevant ES in the living lab area

There is currently an average harvest stock of 310 Efm/ha (= harvestable cubic metre per ha) in the German living lab area. The forest areas of the Archdiocese of Munich-Freising (Stakeholder 1) have an average harvest stock of 271.85 Efm/ha. Significantly higher values are to be expected for the forest areas of large private forest ownership (423.62 Efm/ha).

Political relevance at EU / national level

In general, forestry and forest management are of high political relevance in Germany. The Federal Forest Strategy 2050 pursues the preservation and adaptation of forests to climate change. The “Charta für Holz 2.0” (Charter for Wood 2.0) promotes the sustainable use of wood to reduce CO₂ emissions. In addition, the “Nationale Bioökonomiestrategie” (National Bioeconomy Strategy) focuses on wood as a substitute for fossil resources. In Bavaria, the “Waldpakt 2023” (Forest Pact 2023) strengthens active forest management and rejects set-aside. The “Waldumbauoffensive 2030” (Forest Conversion Campaign 2030) doubles the annual conversion area to create stable mixed forests. The “Initiative Zukunftswald (IZW)” (Future Forest Initiative) and the “Bergwaldoffensive (BWO)” (Mountain Forest Offensive) support forest owners with climate adaptation projects. “Zukunft.Bioökonomie.Bayern” also promotes the use of wood in the economy.

The use of wood as an energy source is currently the subject of intense debate. While wood is considered a renewable energy source, the Federal Environment Agency has questioned the climate neutrality of wood energy, which has led to debates about CO₂ emissions and possible levies. However, the German government has clarified that no CO₂ levy on wood energy is currently planned.

1.3 List of possible indicators for ecosystem services

Ecosystem service	Indicator-type*	Indicator	Indicator unit	Description
Wood provision	Supply	Average annual growth per hectare	$m^3/ha \cdot a$	The average annual wood increment with bark is determined by comparing two survey periods. The increment data of the third National Forest Inventory in Germany refer to the period from 2002 to 2012, taking into account the timber stock (gross increment) removed in the meantime. The hectare figures refer to the average area.
		Absolute stock of derb wood with bark	V_{fm}/ha (= stock cubic metre per ha)	The inventory data refer to the total amount of standing derb wood with bark, whereby the amount of derb wood with a diameter of 7 cm or more at breast height is taken into account. This information can be presented in absolute figures and per hectare of the analysed area.
		Absolute timber stock of derb wood without bark	$E_{fm} \text{ D. o. R. } /ha$ (= harvestable cubic metre of derb wood without bark)	The quantity of harvested timber corresponds to the absolute timber stock of derb wood without bark in harvestable cubic metres of derb wood without bark per hectare ($E_{fm} \text{ D. o. R. } /ha$). One cubic metre of harvested derb wood (E_{fm}) corresponds to one solid cubic metre of stock (V_{fm}) minus approximately ten percent bark loss and ten percent timber harvesting loss.

* There are also indicators for the “demand” (how high is the demand for this ecosystem service?), the “flow” (how much of the ecosystem service provided is utilised) or the “potential” (how high would the natural provision of the ecosystem service be?). In the Forest EcoValue project, we are focussing on supply indicators.

2 Selected indicator for ecosystem services

The indicator best suited to describe the forest ecosystem service provision of wood biomass is

absolute timber stock of timber without bark in $E_{fm} \text{ D. o. R. } /ha$ (= harvestable cubic metre diameter without bark per ha)

2.1 Brief description of the selected indicator

Definition

The amount of wood harvested is given in harvest cubic metres. The **harvestable cubic metre (Efm)** refers to the **usable volume of wood without bark and without gaps** and corresponds to one **stock cubic metre (Vfm)** minus approx. 10% bark loss and 10% timber harvesting loss.

Interpretation of the indicator

The indicator values provide a statement about the wood supply. The higher the indicator value Efm/ha, the higher the supply of wood as a raw material.

Justification for the selection of the indicator

The indicator is easy to understand and is widely accepted in the forestry and timber sector. *Derb* wood in cubic metres is an important indicator for the total usable timber volume (minus bark and spaces) and an important parameter for sawmills, as the indicator describes the available quantity of usable logs (i.e. sawable timber) more accurately than other measures. However, the volume of wood also contains weaker wood assortments, i.e. not only high-quality saw timber, but also industrial wood.

Political significance

According to the fourth Federal Forest Inventory 2022, the average timber stock in Germany's forests is around 300 cubic metres/ha. From a political perspective, this high wood stock emphasises the importance of sustainable forestry. The large stocks offer potential for increased wood utilisation, which can contribute to the substitution of fossil raw materials. However, recent climate-related damage shows that forests are increasingly acting as a carbon source rather than a carbon sink. This emphasises the need for **climate adaptation** and **forest conversion** measures to strengthen the resilience of forests and secure their role in climate protection (BMEL 2024).

2.2 Data sources and documentation of the indicator calculation

Data availability at the level of the Alpine Space cooperation area

The availability of data at national or transnational level is currently unclear. However, as part of the Forest EcoValue project, the ecosystem service “provision of wood biomass” is to be assessed for the entire transnational Alpine region.

2.2.1 Indicator calculation for the forest areas of the Archdiocese of Munich-Freising

Data availability at the pilot area level

The following data is available for the forest areas of the Archdiocese of Munich-Freising at local and national level:

- Digital forest management data from the years 2016 to 2018 in shape format, including information on tree species proportions, age spread, utilisation type, stocking level, harvesting stock in Efm D. o. R./ha for the years 2016 to 2018, etc.

- Information on average annual increments in $m^3/ha \cdot a$ by tree species and average cutting rates in $Efm/ha \cdot a$ by tree species from the fourth National Forest Inventory 2022

The indicator is presented on a **portfolio basis**.

Steps for calculating the indicators for mapping

The forest organisation data (2016 - 2018) is scaled up to the year 2024 based on data from the fourth national forest inventory (2022). The following calculation steps were selected:

1. Determination of the average increments per tree species in $m^3/ha \cdot a$ (see Appendix, Table 1, values for Bavaria) and the average utilisation per tree species in $Efm D. o. R. /ha \cdot a$ from the fourth National Forest Inventory (2012 to 2022) (see Appendix, Table 2, values for Bavaria)
2. Conversion of the average increments per tree species from $m^3/ha \cdot a$ to $Efm/ha \cdot a$ by deducting the harvest loss of 20% (see Appendix, Table 1, last row)
3. Calculation of the change in stock in Efm/ha for the period between the last forest management (2016 - 2018) and the year 2024 from the average increments, minus the utilisation for each tree species, depending on the proportion of tree species in the stand area

Change in stock (period 2016 to 2024) in Efm per ha per tree species = ((Growth in Efm per ha and year – utilisation in Efm per ha and year) * Number of years) * (Proportion of tree species / 100)

Example formula GIS: $[Ei_dgzw_ha] = ((6.15 - 0.16) * [Anz_Jahr]) * ([Ei____] / 100)$

4. Addition of the results from step 3 with the harvesting stock from the forest organisation (2016 to 2018) in Efm/ha for each tree species. The calculation results in the updated, total harvest stock depending on the tree species as of 2024

Stock in Efm/ha per tree species = Result from step 3 + Stock in Efm/ha per tree species (“Forsteinrichtung” (forest management) 2016/2018)

Example formula GIS: $[Ei_Efm_neu] = [Ei_dgzw_ha] + [Ei_Efm]$

5. The sum of all updated, absolute timber stocks D.o.R. in Efm/ha per tree species results in the total timber stock D.o.R. in Efm/ha per stand

Example formula GIS: $[bio_2] = [Dgl_Efm_neu] + [Elae_Efm_neu] + [Bu_Efm_neu] + [Ta_Efm_neu] + [Ei_Efm_neu] + [Kie_Efm_neu] + [Elbh_Efm_neu] + [Fi_Efm_neu] + [sLbh_Efm_neu]$

Stock of $Efm D.o.R. /ha$ (fully stocked) = Stock of Douglas fir + Stock of noble hardwood + Stock of beech + Stock of fir + Stock of oak + Stock of pine + Stock of European larch + Stock of spruce + Stock of other hardwoods

6. Since the values were representative of fully stocked stands, they were adjusted with previously revised stocking

Stock of Efm D.o.R. /ha (adjusted) = Stock of D.o.R. in Efm/ha (fully stocked) * Stocking rate of the stand area

Example formula GIS: [bio_new] = [bio_2]*[bgr_new]

2.2.2 Indicator calculation for the forest areas near Waakirchen

Data availability at the pilot area level

The following data is available for the forest areas near Waakirchen

- Digital terrain model in raster format (grid size 1.0 m)
- Digital surface model in raster format (grid size 0.8 m)
- Information on deciduous and coniferous wood from the High Resolution Layer Forest Types (Copernicus 2018) in raster format (grid size 10 m)
- Analogue economic map/forest management map (status 2016) of the forest owner with information on the divisions, subdivisions and the age classes of the respective subdivisions. This has been digitised and is available in shape format.
- Parcel map of the forest owner in Esri shape format
- Auxiliary forestry tables for estimating harvest stocks D.o.R. in Efm/ha according to Assmann & Franz (1963): Spruce, preliminary yield table, average yield level (StMLEF 2018)

The indicator is presented on a **stand-by-stand basis**.

Steps for calculating the indicators for mapping

GIS processing:

- Digitisation of the analogue economic map (2016) with age classes and stock boundaries
- Creation of stand numbers
- Determination of the vegetation or tree height (normalised digital surface model, nDSM) from the difference between the digital surface model (grid width 0.8 cm) and the digital terrain model (grid width 1.0 m) (raster calculator in QGIS)
- Point extraction of vegetation heights from the nDSM (Raster to Point in ArcGIS Pro) and appending the inventory numbers to point shapes (Spatial join)
- Determination of statistical values of the vegetation height distribution for each stand number from the point layer (1st and **3rd quantile**, mean value, median)
- Further use of the height values of the **3rd quantile** per stand as “upper stand height”

Estimation of the timber stock using auxiliary forestry tables (Assmann & Franz 1963):

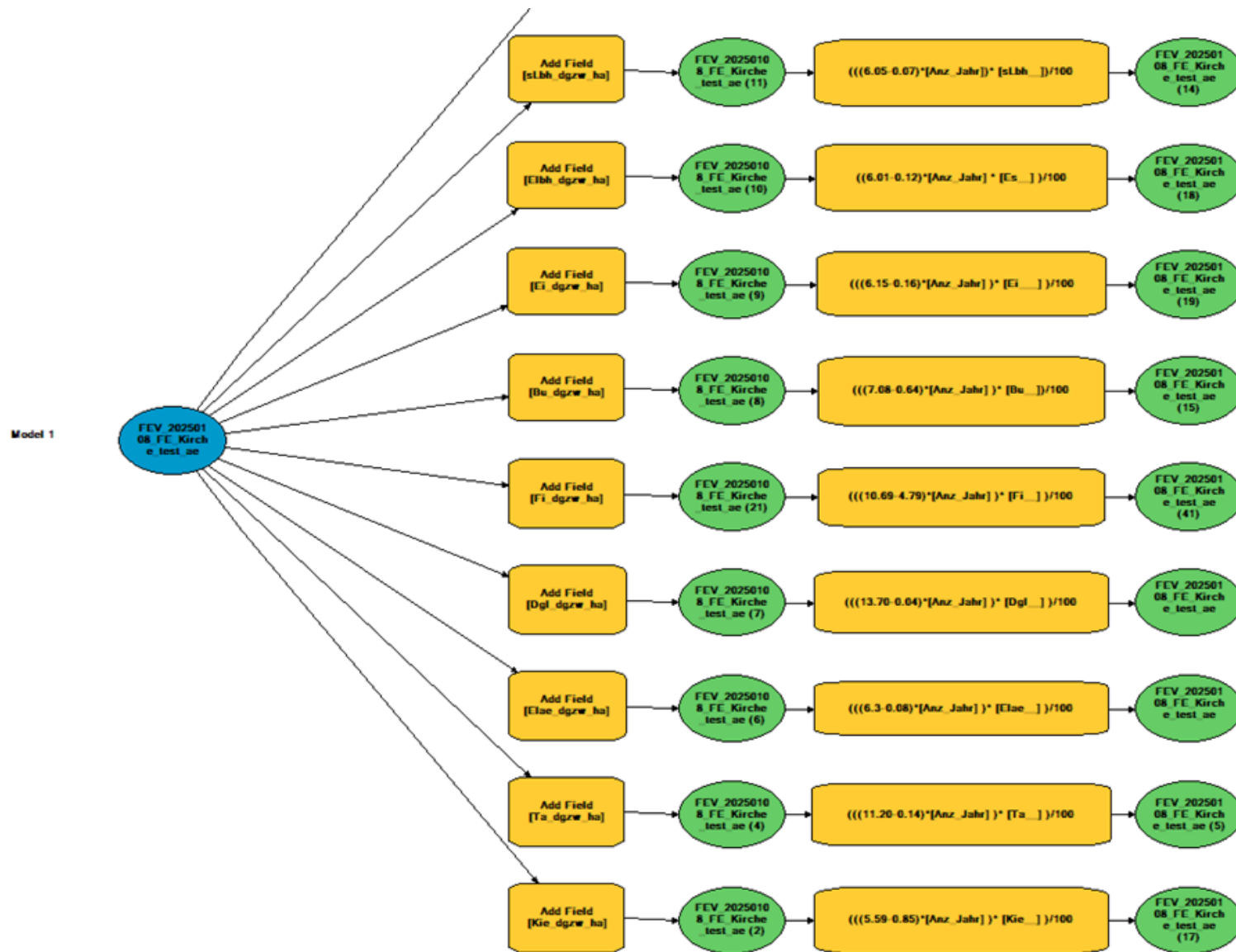
- *Determination of the top-height bonus from the top-height bonus curves (Assmann & Franz 1963)*
- *Determination of the stock E_{fm} D. o. R. /ha (total output of derb wood) as a function of the top-height bonus, the stand age and the tree height*
- *Interpolation of the values to estimate intermediate values between known measured values (= top-height bonuses) if no clear top-height bonuses could be read off.*

3 References

BMEL (Bundesministerium für Ernährung und Landwirtschaft) (Ed.) (2024): *Der Wald in Deutschland. Ausgewählte Ergebnisse der vierten Bundeswaldinventur.*

LWF (Bayerische Landesanstalt für Wald und Forstwirtschaft) (Ed.) (2025): *Holzeinschlag.* Online available at <https://www.lwf.bayern.de/forsttechnik-holz/holzmarkt/051095/index.php>, checked on 4/30/2025.

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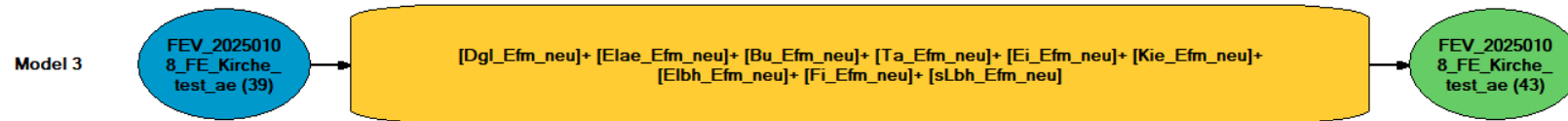


Table 1: Increase in stock [m³/ha*a] by federal state and tree species group (filter: period = 2012-2022)

Federal State	Unit	Oak (Quercus)	Beech (Fagus)	Ash (Fraxinus)	Maple (Acer)	Other deciduous trees long life span	Birch (Betula)	Alder (Alnus)	Other deciduous trees low life span	All deciduous trees	Spruce (Picea)	Fir (Abies)	Douglas fir (Pseudotsuga)	Pine (Pinus)	Larch (Larix)	All conifers	All tree species
Baden-Wuerttemberg	[m ³ /ha*a]	7,23	8,36	6,67	7,54	5,96	6,14	7,48	6,00	7,56	13,12	14,40	16,88	6,24	6,78	12,62	10,21
Bavaria	[m ³ /ha*a]	7,69	8,85	7,52	7,80	6,52	5,15	8,59	7,56	7,93	13,37	14,01	17,13	6,98	7,88	11,54	10,20
Berlin	[m ³ /ha*a]	4,68	9,03	8,60	7,90	0,77	2,21	0,00	8,72	5,12	0,00	0,00	0,00	5,43	4,89	5,42	5,28
Brandenburg	[m ³ /ha*a]	6,98	9,83	7,85	6,92	6,20	3,70	8,02	4,48	6,42	13,40	24,18	13,91	8,98	9,34	9,14	8,45
Hesse	[m ³ /ha*a]	6,72	8,30	7,58	9,06	5,95	5,59	7,30	5,47	7,51	13,52	17,71	15,30	7,18	7,08	11,23	8,89
Mecklenburg-Western Pomerania	[m ³ /ha*a]	7,85	10,42	7,90	8,80	6,64	4,52	7,85	7,73	8,01	14,20	23,00	15,84	10,04	11,20	10,94	9,47
Lower Saxony	[m ³ /ha*a]	7,48	9,17	7,53	8,89	6,10	3,77	8,96	5,95	7,36	12,18	23,84	14,77	7,38	8,10	9,33	8,39
North Rhine-Westphalia	[m ³ /ha*a]	7,64	8,78	8,35	8,58	6,35	3,55	7,98	6,76	7,49	11,79	14,40	10,60	6,62	7,24	10,34	8,60
Rhineland-Palatinate	[m ³ /ha*a]	6,32	8,50	8,15	7,65	5,36	5,66	6,84	6,31	7,12	12,97	14,63	15,54	5,45	7,19	11,10	8,61
Saarland	[m ³ /ha*a]	8,69	11,60	3,93	9,61	6,97	6,35	8,84	5,99	8,61	14,21	81,62	18,73	4,71	7,36	12,29	9,46
Saxony	[m ³ /ha*a]	8,18	8,90	7,12	9,16	6,77	4,07	7,74	6,42	6,88	13,33	18,09	8,34	8,64	9,61	11,08	9,66
Saxony-Anhalt	[m ³ /ha*a]	6,23	7,57	7,85	6,09	5,70	3,51	8,82	5,62	6,20	12,25	12,64	10,33	8,43	8,43	8,98	7,74
Schleswig-Holstein	[m ³ /ha*a]	8,97	11,78	7,76	10,67	9,55	3,91	7,36	8,35	9,06	14,12	23,64	14,96	7,55	8,49	11,83	9,99
Thuringia	[m ³ /ha*a]	6,51	6,73	6,47	5,53	4,76	4,45	6,60	3,77	6,08	11,48	8,51	17,25	8,46	7,59	10,46	8,48
Hamburg + Bremen	[m ³ /ha*a]	7,43	9,38	11,11	7,27	7,09	3,58	3,83	9,78	7,35	11,31	0,00	17,91	6,19	4,63	7,37	7,35
Germany (all states)	[m ³ /ha*a]	7,23	8,69	7,36	7,90	6,09	4,33	8,13	6,36	7,41	12,98	14,70	15,40	8,08	7,98	10,78	9,23
Values for Bavaria converted to	[Efm D. o. R. /ha*a]	6,15	7,08	6,01	6,24	5,22	4,12	6,87	6,05	6,35	10,69	11,20	13,70	5,59	6,30	9,23	8,16

Basis: Germany, combined area of timber ground of both inventories, accessible**, including gaps in the stand, trees from 7 cm Bhd in the main stand or plenter forest, stand-internal, tree volume: BDat3. 0 (spline function, 2013), Sloboda (growth), grid: 16km²: NI, HE, SL, BY, BE / 8 km²: NI, BY, SN, TH / 4km²: SH, NW, RP, BW, BB, MV, ST (intersection inventory grid for BWI period 2012-2022 including the LWI of NW and BB); ideal area reference (according to stand area share)

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Table 2: Average utilisation (solid cubic metres harvested o. R.) [$\text{m}^3/\text{ha} \cdot \text{a} = \text{Efm D. o. R.} / \text{ha} \cdot \text{a}$] by federal state and tree species group (filter: period = 2012-2022)

Federal State	Unit	Oak (Quercus)	Beech (Fagus)	Ash (Fraxinus)	Maple (Acer)	Other deciduous trees long life span	Birch (Betula)	Alder (Alnus)	Other deciduous trees low life span	All deciduous trees	Spruce (Picea)	Fir (Abies)	Douglas fir (Pseudotsuga)	Pine (Pinus)	Larch (Larix)	All conifers	All tree species
Baden-Wuerttemberg	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,20	1,50	0,38	0,12	0,11	0,02	0,03	0,08	2,44	4,21	0,72	0,19	0,31	0,08	5,52	7,96
Bavaria	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,16	0,64	0,12	0,05	0,05	0,06	0,04	0,07	1,20	4,79	0,14	0,04	0,85	0,08	5,90	7,10
Berlin	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,45	0,30	0,00	0,00	0,00	0,24	0,00	0,08	1,06	0,00	0,00	0,00	2,53	0,08	2,60	3,66
Brandenburg	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,15	0,15	0,02	0,01	0,07	0,13	0,02	0,04	0,58	0,26	0,00	0,05	3,18	0,07	3,55	4,14
Hesse	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,34	2,13	0,05	0,04	0,04	0,07	0,00	0,05	2,71	4,57	0,00	0,19	0,46	0,20	5,42	8,13
Mecklenburg-Western Pomerania	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,17	0,54	0,35	0,03	0,05	0,14	0,15	0,08	1,51	1,06	0,01	0,07	1,70	0,17	3,01	4,53
Lower Saxony	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,30	0,87	0,06	0,02	0,03	0,13	0,07	0,12	1,61	2,70	0,02	0,11	1,37	0,22	4,42	6,03
North Rhine-Westphalia	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,37	0,92	0,09	0,06	0,06	0,08	0,02	0,18	1,78	7,30	0,02	0,05	0,31	0,15	7,83	9,61
Rhineland-Palatinate	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,38	1,12	0,03	0,04	0,08	0,07	0,02	0,07	1,81	2,95	0,06	0,37	0,35	0,11	3,84	5,65
Saarland	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,57	1,27	0,07	0,09	0,18	0,11	0,00	0,11	2,38	1,49	0,00	0,26	0,40	0,09	2,25	4,63
Saxony	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,14	0,16	0,01	0,05	0,02	0,24	0,02	0,08	0,72	4,03	0,00	0,00	1,40	0,18	5,61	6,33
Saxony-Anhalt	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,29	0,33	0,09	0,03	0,09	0,13	0,01	0,13	1,11	2,43	0,00	0,01	2,17	0,14	4,75	5,86
Schleswig-Holstein	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,41	0,98	0,33	0,08	0,06	0,09	0,11	0,13	2,18	2,12	0,18	0,10	0,37	0,42	3,19	5,37
Thuringia	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,14	1,13	0,17	0,06	0,03	0,05	0,01	0,04	1,63	5,20	0,00	0,01	0,56	0,16	5,93	7,56
Hamburg + Bremen	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,83	0,41	0,00	0,00	0,00	0,74	0,09	0,22	2,29	0,61	0,00	0,00	0,89	0,00	1,50	3,79
Germany (all states)	[$\text{m}^3/\text{ha} \cdot \text{a}$]	0,24	0,89	0,13	0,05	0,06	0,09	0,04	0,09	1,58	3,72	0,13	0,10	1,06	0,13	5,15	6,73

Basis: Germany, combined area of timber ground of both inventories, accessible**, including gaps in the stand or in the stand, utilised trees from 7 cm Bhd of all stand layers, stand-internal, tree volume: BDat3. 0 (spline function, 2013), Sloboda (growth), grid: 16 km²: NI, HE, SL, BY, BE / 8 km²: NI, BY, SN, TH / 4km²: SH, NW, RP, BW, BB, MV, ST (intersection inventory network for BWI period 2012-2022 including the LWI of NW and BB); real area reference (according to tract share))

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Alpine Space

Forest EcoValue

Forest EcoValue

Promotion of diverse ecosystem services of the mountain forest through new circular/green/organic markets and value chains

Indicator factsheet on the ecosystem service Water provision

Thomas Dichtl
PP6 ifuplan

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1 Definition and background of ecosystem services

Title of the ecosystem service

Provision of drinking water

1.1 Definition of ecosystem services

Brief description of the ecosystem service

The ecosystem service of providing drinking water includes the natural filtration and purification of water suitable for human consumption. Forests, along with wetlands and aquifers, play a crucial role in maintaining water quality. This service is essential for human health and well-being. The protection and sustainable management of forest ecosystems is therefore of great importance.

Classification within the CICES system

Section:	Provision
Division:	Water
Group:	Groundwater for use as food, materials or energy
Class:	Groundwater for drinking
Class type:	By amount, type, source
CICES code:	1.1.2.2

1.2 Background information on ecosystem services

All day relevance in the living lab area

The ecosystem service of the drinking water supply in the living lab in the Alpine foothills is of high daily relevance. Natural filtration through soil and vegetation enables the provision of high-quality drinking water in these areas, which can often be used without expensive treatment. This natural water purification supplies the local population and saves considerable costs for alternative treatment measures.

Information to status of the relevant ES in the living lab area

The supply of drinking water in the foothills of the Alps is currently stable, but climate change could affect water quality and jeopardise natural filtration through soil and vegetation. In particular, damage to forests due to heat, drought and pest infestation weakens their filter function. In addition, more frequent heavy rainfall events could flush more pollutants into the groundwater.

Political relevance at EU / national level

Drinking water protection is of high political relevance both nationally and in the EU. The new EU Drinking Water Directive was adopted in 2020 and is currently in the implementation phase. The directive introduces stricter limits and a European certification procedure, which has far-reaching implications for industry and consumers. The European Parliament considers the right to clean drinking water to be part of the broader EU water policy.

1.3 List of possible indicators for ecosystem services

Ecosystem service	Indicator-type*	Indicator	Indicator unit	Description
Provision of drinking water	Supply	Forest cover	Clear-cut area in m ² or pro rata in %	Permanent forest cover is beneficial for drinking water quality. Clear-cutting has a negative impact on the supply of drinking water.
		Proportion of hardwoods	%	Percentage of hardwoods. A higher proportion of hardwoods in forests leads to better drinking water quality and higher groundwater recharge.
		Chemical status of the groundwater	mg/l	Nitrogen (in the form of nitrate) is a typical parameter for assessing the quality of drinking water under forest conditions. Values below 2.5 mg/l are considered harmless, while values above 10 mg/l are critical.

* There are also indicators for the “demand” (how high is the demand for this ecosystem service?), the “flow” (how much of the ecosystem service provided is utilised) or the “potential” (how high would the natural provision of the ecosystem service be?). In the Forest EcoValue project, we are focussing on supply indicators.

2 Selected indicator for ecosystem services

Forest structure indicator (proportion of hardwood + forest cover)

2.1 Brief description of the selected indicator

Definition

Forest structure indicator

Interpretation of the indicator

The forest structure indicator takes into account the proportion of deciduous trees in the stands and the forest cover, or the presence of bare areas. A higher proportion of deciduous trees in forests leads to better drinking water quality, as deciduous trees absorb fewer pollutants from the air than conifers and release less nitrate into seepage water. In addition, deciduous forests produce more seepage water than

coniferous forests, which leads to higher groundwater recharge and dilution of pollutants (Hegg et al. 2004; Rothe & Mellert 2004).

Forest cover is relevant because (permanent) forests contribute to nutrient uptake through their vegetation, which reduces nitrate concentrations in groundwater while maintaining soil structure, retaining water and thus improving water quality. In contrast, clear-cutting can impair these positive effects by destabilising the soil structure and reducing water filtration.

Forest inventory data from forest owners provide precise tree species proportions, from which a percentage of hardwood can be calculated. Where inventory data is missing, satellite data can be used. Five levels can be formed from the proportion of hardwood (see Table 1). A higher level value (e.g. 5) of the forest structure indicator means a higher potential supply of drinking water than lower values (e.g. 2)

As bare areas are the worst for water supply due to nitrate leaching, they are given the lowest level value “0”. In the forest classification, this corresponds to the areas “U” (= unstocked). Areas without a designated type of use correspond to forest meadows, paths, agricultural areas, wood storage areas, pipeline corridors and similar. These were not taken into account.

Table 1: Classification of the levels of the forest structure indicator

Forest structure indicator	Forest cover	Percentage of deciduous trees per stand
0	Bare surface	-
1	Forest	0-20
2	Forest	21-40
3	Forest	41-60
4	Forest	61-80
5	Forest	81-100

Justification for the selection of the indicator

The indicator was chosen because it is **easy to understand** and at the same time reflects the **two most important stand parameters** (proportion of hardwoods and forest cover) that are decisive for drinking water quality. The selection is based on the following mechanisms:

1. Nitrate reduction under deciduous trees

Deciduous forests have a **significantly lower nitrate concentration in seepage water** compared to coniferous forests. This is due to the lower pollutant input via the leaf surface and the reduced acid formation (Rothe & Mellert 2004).

2. Deposition of pollutants by conifers

Conifers have a **higher leaf area index**, which favors the leaching of air pollutants, but at the same time leads to increased **dry deposition** and **nitrate accumulation in the crown flow**. This results in a higher acid and nitrogen input into the groundwater (Hegg et al. 2004; Rothe & Mellert 2004).

3. **Deep nutrient filtration**

Deciduous trees have **deeper rooting zones**, which enable a **longer filter path for seepage water**. This effectively reduces the nitrate concentration - especially in the case of high nitrogen inputs from the air (Hegg et al. 2004).

4. **Stable nitrogen supply in mineral soil humus**

Deciduous forest soils form **stable mineral soil humus**, which stores nitrogen in an organically bound form and thus reduces leaching into the groundwater (Hegg et al. 2004).

The indicator combines **practical applicability** (simple data collection via forest inventories or remote sensing) with **scientific relevance**, as it allows direct conclusions to be drawn about the influence of forest structure on drinking water quality.

Political significance

The **forest structure indicator** provides information for political measures and decisions. It can support the prioritisation of deciduous forest promotion and the restriction of clear-cutting in drinking water critical areas. It can also help with the designation of protection zones and spatial planning in order to minimise conflicts between forest use and drinking water safety. The indicator also enables the evaluation of forest services for compensation payments and can be incorporated into the pricing of drinking water. Through these applications, it can contribute to the implementation of environmental and water protection goals.

2.2 Data sources and documentation of the indicator calculation

Data availability at the level of the Alpine Space cooperation area

Where forest inventory data is missing, remote sensing data can be used to derive the mixture from Corine Land Use data. These have a resolution of 10x10 meters. For a uniform approach, these are related to the stand size.

The clear-cut areas can be determined using the heights of the normalised digital surface model (nDSM). For the Bavarian Alpine region this is available in 1x1m resolution.

Data availability at the pilot area level

Forest inventory data may be available as small-scale data. These are available on a stand-by-stand basis. Where forest inventory data is missing, remote sensing data can be used to derive the mixture and forest cover.

Steps for calculating the indicators for mapping

Mixture:

The proportions of hardwood can be calculated from the tree species proportions using the existing forest management values. Where this information is missing, Copernicus data can be used. The grid values are then calculated proportionally in relation to the stand size. The shape of the stand can influence the results.

Forest cover:

Information on bare areas can be calculated from the difference between the digital surface model (DSM1) and the digital terrain model (DTM1). The resulting normalised surface model was then vectorised and all height values between 0 and 1 m were considered as unstocked. With a minimum contiguous area of 1,000 m² and a minimum width of 30 m, this area was identified as bare ground and included in the assessment accordingly.

3 References

- Hegg, C.; Jeisy, M. & Waldner, P. (2004). Wald und Trinkwasser. Eine Literaturstudie, WSL - Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft.
- Rothe, A. & Mellert, K. H. (2004). Effects of Forest Management on Nitrate Concentrations in Seepage Water of Forests in Southern Bavaria, Germany. In: *Water, Air, & Soil Pollution* 156 (1), S. 337–355.

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Promotion of diverse ecosystem services of the mountain forest through new circular/green/organic markets and value chains

Indicator factsheet on the ecosystem services Recreation

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PP6 ifuplan

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1 Definition and background of ecosystem services

Title of the ecosystem service

Recreation

1.1 Definition of ecosystem services

Brief description of the ecosystem service

The forest ecosystem service recreation refers to the intangible benefits that people derive for their well-being and health from spending time in forest ecosystems. This cultural service includes opportunities for stress reduction, mental and physical regeneration as well as active and passive leisure activities in a natural environment. Studies show that the economic value of this recreational service is estimated to be significantly higher than the direct economic returns from timber production. This emphasises the need to take appropriate account of recreational benefits in forest management strategies and spatial planning decision-making processes.

Classification within the CICES system

Section:	Cultural
Division:	Direct interactions with outdoor living systems that depend on presence in the environment
Group:	Physical and experiential interactions with the natural environment
Class:	Characteristics of living systems that facilitate activities that promote health, recreation or pleasure through passive or observational interactions
Class type:	By type of living system or environmental setting
CICES code:	3.1.1.2

1.2 Background information on ecosystem services

All day relevance in the living lab area

Recreation in the forest is of paramount importance in the living lab area. This region in the foothills of the Alps to the south of Munich is characterised by its proximity to the city and at the same time its scenic attractiveness. It offers diverse forest areas that are used intensively for leisure and recreation. The forests serve as important local recreation areas for the residents of the greater Munich area and contribute significantly to improving the quality of life.

Information to status of the relevant ES in the living lab area

In recent years, the intensity of utilisation of forests for recreational purposes has increased significantly, leading to growing management challenges, particularly with regard to the balance between

recreational use, nature conservation and forestry interests. The high demand for forest-based recreation emphasises the central role of this ecosystem service for the region.

Political relevance at EU / national level

The ecosystem service “recreation” is politically recognised at both EU and national level and is reflected in specific strategies. At EU level, the *EU Biodiversity Strategy 2030* emphasises the importance of near-natural areas for recreation and health, while the *Green Infrastructure Strategy* and the *Natura 2000 network* promote the protection and sustainable use of particularly valuable areas. Nationally, the recreational function of the forest is supported by the “*Bundeswaldgesetz*” (Federal Forest Act) and state forest laws, which enable multifunctional use of the forest. Particularly in the Alpine region south of Munich, a balance between nature conservation, forestry utilisation and the high demand for recreational opportunities is essential.

1.3 List of possible indicators for ecosystem services

Ecosystem service	Indicator-type*	Indicator	Indicator unit	Description
Recreation	Supply	Development	m / ha	The accessibility of potential recreational areas can be a measure of recreation via development.
		Naturalness	dimensionless	The perceived naturalness is a subjective value that can be recorded empirically via surveys.
		Development stage of the forest / stand age	JP, JD, AD; VJN or years	The age of the stand can be a measure of the attractiveness of a forest for visitors. Old stands and stands with a mixture of different stages of development are considered particularly attractive. Data can be determined with inventories.
		View	Field of vision in °	The view can be determined using a GIS analysis and, in mountainous terrain, is a measure of the attractiveness of an area. The angular area that can be seen unobstructed from a viewpoint.
		Visitor facilities	pcs / ha pcs / path length	The number of existing facilities (benches, information boards, wayside crosses) can, as infrastructure for those seeking recreation, be a quantitative factor for recreation.

* There are also indicators for the “demand” (how high is the demand for this ecosystem service?), the “flow” (how much of the ecosystem service provided is utilised) or the “potential” (how high would the natural provision of the ecosystem service be?). In the Forest EcoValue project, we are focussing on supply indicators.

2 Selected indicator for ecosystem services

Potential recreational value (development of the area with paths combined with perceived naturalness of the forest).

2.1 Brief description of the selected indicator

Definition

Potential recreational value

Interpretation of the indicator

The **potential recreational value** is an assessment approach that classifies forest areas based on specific criteria with regard to their suitability for recreational use. It describes the perceived naturalness within a 40 metre radius of the existing trail network (based on Schulz & Meyer 2021). The aim of this assessment is to determine the attractiveness and benefits of forest areas for leisure and recreation. The categorisation is based on three main factors: **Proximity to the trail network**, **age of the forest** and **mix of stands**. These factors significantly influence the perception and usability of the forest areas by visitors (Edwards et al. 2010; Schulz & Meyer 2021).

Criteria of potential recreational value

1. Proximity to the trail network

The accessibility of a forest area plays a decisive role in its recreational value. Areas within 40 metres of a network of paths are rated as more accessible and therefore more attractive than those outside this area.

2. Age of the forest

The age of the forest stands is divided into three categories:

- *Clear areas*: Areas without trees that are least attractive for recreation.
- *Young stands*: Areas with young stands (e.g. young stands or young thinnings) that offer a medium recreational value due to their structure and aesthetics.
- *Old stands*: Areas with older stands (e.g. old thinnings or previous utilisations) that have a higher recreational value.

3. Mixed proportion

Mixed stands (stands with deciduous and coniferous tree species) are perceived as more aesthetically pleasing than pure stands (monotypic tree stands), which increases their recreational value.

Classification of the potential recreational value

The combination of these three factors results in a scale of 1 to 9 (see Table 1), with higher values indicating a higher potential recovery value:

- **1:** Clear areas without consideration of the path network, which offer little recreational value.
- **2-5:** Areas outside 40 metres of the path network, whose recreational value increases depending on age and proportion of mixed use.
- **6-9:** Areas within 40 metres of the path network, which have a higher recreational value due to their better accessibility and, depending on their age and mixed stock.

Exemplary interpretation

- An area with a value of **9** lies within 40 metres of a path, consists of old-growth forest and has a high proportion of mixed forest - it offers optimal conditions for recreation.
- An area with a value of **2** lies outside 40 metres of a path, consists of young forest and is a pure stand - it has a low recreational value.

Table 1: Potential recreational value depending on development, age, mixture

Pot. Recreational value	Path network	Age	Mixture
1	-	Clear area	-
2	Outside 40m	Young	Pure stock
3	Outside 40m	Young	Mixed stock
4	Outside 40m	Old	Pure stock
5	Outside 40m	Old	Mixed stock
6	Within 40m	Young	Net stock
7	Within 40m	Young	Mixed stock
8	Within 40m	Old	Net stock
9	Within 40m	Old	Mixed stock

Justification for the selection of the indicator

The indicator combines two key characteristics that make forests attractive to recreationists. Various publications point out that recreationists prefer forests that are old and mixed (Schulz & Meyer 2021). A low intensity of management is also considered attractive. Since the management intensity is difficult to derive at stand level from forest management data, it is considered to be constant over the forest enterprise. Stand age and tree species mix can be taken very well from the forest organisation.

Political significance

The potential recreational value as an indicator for the ecosystem service of recreation provides a basis for discussion for resource allocation and spatial planning, but must be combined with other parameters for well-founded decisions. Despite its simplicity, it provides information for political measures in the areas of infrastructure development, nature conservation and health policy. As a decision-making aid, the indicator enables the formulation of specific targets for improving the recreational function and supports cost-benefit analyses for investments in recreational areas.

2.2 Data sources and documentation of the indicator calculation

Data availability at the level of the Alpine Space cooperation area

Development: OpenStreetMap data is available for the entire Alpine region. These show much better coverage for the area under consideration than the public administrative data on routes. However, the quality of the data can vary.

Stand characteristics: Large-scale Copernicus data can be used to determine the proportion of deciduous/coniferous trees in the Alpine region. The height can also be determined using the normalised digital surface model (nDSM). This is available in 1x1m resolution for the Bavarian Alpine region.

Data availability at the pilot area level

Development: Although local administrative data is available for this purpose, it is only suitable to a limited extent. They lack a considerable proportion of the low-order paths and trails that are of particular interest to recreational users. Depending on the intensity of use of the area, publicly available data from leisure apps could possibly form a data basis for access routes that are actually used.

Stand characteristics: Forest management data from the forest owners is available for this purpose, from which the perceived naturalness of the forests can be derived. The timeliness and scope of the data varies depending on the forest owner. The forest inventory data is available on a stand-by-stand basis. Where forest inventory data is missing, large-scale data can be used.

Fig 1. Contribution of each FMA to recreational score, by region

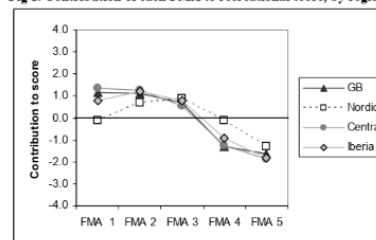


Fig 2. Contribution of each phase of development to recreational score, by region

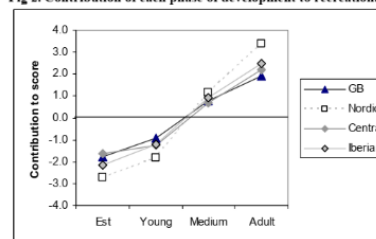


Fig 3. Contribution of each tree species type to recreational score, by region

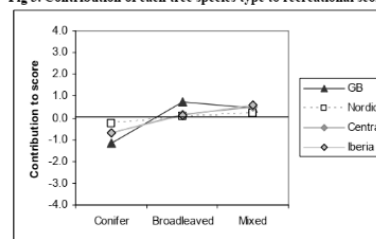


Figure 1: Influence of management intensity, stand age and mixing ratio on recreational suitability - results according to Edwards et al. (2010)

Steps for calculating the indicators for mapping

Development:

The development data from OpenStreetMap is available as the shape 'gis_osm_roads_free_1'. In the 'fclass' field, the roads relevant for the recreational search are filtered. These are assumed to be all roads and paths with no to very low traffic volumes. The categories shown in Table 2 are considered relevant or excluded for recreational access:

Table 2: OSM route categories considered and excluded

OSM category	German equivalent	Consideration
Motorway, Motorway_link	Autobahn, Autobahnzufahrt	Excluded
Trunk, trunk_link	Schnellstraße	Excluded
Primary, primary_link	Bundesstraße	Excluded
Secondary, secondary_link	Staatsstr. Größere Kreisstr.	Excluded
Tertiary, tertiary_link	Einfache Kreis- oder Gemeindestr.	Excluded
Track (grad1-5)	Befahrbarer Weg	Considered
Path	Pfad	Considered
Service	Erschließungsweg	Considered
Steps	Stufen	Considered
Cycleway	Radweg	Considered
Unclassified		Considered
Footway	Gehweg	Considered

Mixture:

The proportions of deciduous and coniferous wood can be determined from the listed proportions of tree species from the existing forest management values. Where this information is missing, Copernicus data can be used. The grid values are then calculated proportionally in relation to the stand size. A stand is mixed if it contains more than 10 % deciduous and coniferous wood. This corresponds to the definition of the German National Forest Inventory (*Bundeswaldinventur (BWI)*).

When evaluating the stands according to age, the type of use of the forest management is used (see Table 3). This would also be possible directly via the age, but the type of use seemed simpler. The utilisation types young stand management (JP) and young thinning (JD) were considered as “young” and the utilisation types old thinning (AD) and regeneration utilisation (VJN) as “old”. Long-term treatment (LB) are medium to very old stands with a frequently uneven-aged structure and are therefore classified as “old”.

Table 3: Allocation of types of use to age groups

„Age”	Type of utilisation of the forest management	Comment
	ZERO	No forest
Clear	U	Clear area
Young	JP, JD	Young stocks
Old	AD, VJN, LB, WA	Old stocks

Commercial forest not in regular use (WA) are areas without forestry use but with traffic safety measures and were rated as “old”. Areas of the use type “Unstocked” (U) cannot be assigned to any tree species; they are clear-cut areas and are assigned the lowest value 1, regardless of their distance from the path. Areas without a designated type of use corresponded to forest meadows, paths, agricultural areas, timber yards, power lines and the like. These were not taken into account.

If this information is not available in the forest management plan, publicly available data can be used. If only a paper map of the forestry survey is available, it can be digitised and the age can be read from it. Information on clear-cut areas can be calculated from the difference between the digital surface model (DSM1) and the digital terrain model (DTM1). For this purpose, the raster data was vectorised and all height values between 0 and 1.5 m were evaluated as unstocked. With a contiguous minimum area of 1,000 m² and a minimum width of 30 m, this area was identified as clear area.

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Alpine Space

Forest EcoValue

Forest EcoValue

Promotion of diverse ecosystem services of the mountain forest through new circular/green/organic markets and value chains

Indicator factsheet on the ecosystem service Protection against natural hazards

Leo Krogmann

PP6 ifuplan

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1 Definition and background of ecosystem services

Title of the ecosystem service

Protection against natural hazards

1.1 Definition of ecosystem services

Brief description of the ecosystem service

A large number of natural hazards can pose a risk to human health and infrastructure. Ecosystems can mitigate the effects of natural hazards. Forests ensure that rockfalls are intercepted and the triggering of avalanches is prevented. In addition, the roots ensure greater stability of the terrain, which can prevent slope failures. The protection and reforestation of mountain forests is therefore of great importance.

Classification within the CICES system

Section:	Regulating and maintaining
Division:	Regulation of baseline flows and extreme events
Group:	Regulation of baseline flows and extreme events
Class:	Buffering and damping of mass movements
Class type:	By type of habitat or geographical context
CICES code:	2.2.3.1

1.2 Background information on ecosystem services

All day relevance in the living lab area

Protection against natural hazards from forests is of daily importance for forest owners, forest users, infrastructure users and residents on the steep slopes of mountain forests.

Information to status of the relevant ES in the living lab area

The service of protection against natural hazards is largely important in the area of the Tegernsee mountains in the study area. There is a high risk of numerous natural hazards, such as rockfall, slope failures and avalanches. There are some forests there that contribute to protection against natural hazards. There are avalanche protection forests according to Art. 6 of the Bavarian Forest Act (*Bayerisches Waldgesetz - BayWaldG*) and protection forests according to Art. 10 BayWaldG. The other parts of the study area are located in areas that are less susceptible to geogenic natural hazards, as there is no great relief energy, for example. Only to the west of Großweil is there still a risk of shallow slope failures in a small corner of the study area. In the vicinity of the study area, however, the natural hazard of flooding plays a major role. Due to the massive human intervention in the natural drainage behaviour and heavy rainfall events, which have already intensified and increased as a result of climate change,

there is a great risk of flooding and inundation. Numerous measures are therefore being taken to minimise the consequences. These include the designation of floodplains, for example to preserve water retention areas and the construction of new dams (Kreisstadt Miesbach 2025).

Political relevance at EU / national level

The topic plays a major role politically, with the strongest focus on flood protection. This is because floods affect the most people overall and the damage is often enormous. However, numerous other natural hazards are also taken into account at a political level. Political efforts are therefore being made at EU, national and regional level to maintain and expand protection against natural hazards. For example, there is the Bavarian “Bergwaldoffensive” (Mountain Forest Offensive), which is committed to ensuring that mountain forests are adapted to climate change (StMELF 2024). The EU Biodiversity Strategy 2030 also includes measures for the conservation and sustainable management of forests with a protective function. At national level, the “Bundeswaldgesetz” (Federal Forest Act) contributes to the protection of forests.

1.3 List of possible indicators for ecosystem services

Ecosystem service	Indicator-type*	Indicator	Indicator unit	Description
Protection against natural hazards	Supply	Percentage of forest per slope	%	Forests can minimise the risk of natural hazards on steeper slopes
		Percentage of forest, protective forest or functional forest per survey area	ha	Protective forest areas according to official designation

* There are also indicators for the “demand” (how high is the demand for this ecosystem service?), the “flow” (how much of the ecosystem service provided is utilised) or the “potential” (how high would the natural provision of the ecosystem service be?). In the Forest EcoValue project, we are focussing on supply indicators.

2 Selected indicator for ecosystem services

Percentage of forest, protective forest or functional forest per survey area

2.1 Brief description of the selected indicator

Definition

The proportion of forest reflects the percentage of forest cover in an area.

Interpretation of the indicator

The proportion of forest in an area has a significant impact on the occurrence and extent of natural hazards. Forests slow down and protect against shallow landslides and avalanches and can absorb rockfalls. This is because their roots increase soil stability, prevent the triggering of avalanches and tree

trunks act as an obstacle to rockfalls. Although forests cannot guarantee complete safety, the consequences can be greatly mitigated (Perzl 2006).

Justification for the selection of the indicator

The proportion of forest can be easily determined by analysing aerial photographs or calculated using land cover or protective forest maps. This factor has also been found to be highly significant for the probability of natural hazards.

Political significance

The positive effects of forests on natural hazards show policymakers that reforestation and forest protection programmes can be a sensible method of mitigating the consequences and frequency of natural hazards. As climate change will lead to an increase in extreme weather events, which are one of the main causes of natural hazards, political measures that lead to the preservation and expansion of protective forests are of great importance.

2.2 Data sources and documentation of the indicator calculation

Data availability at the level of the Alpine Space cooperation area

The availability of data at national or transnational level is unclear. If no corresponding aggregated map of protected assets is available at national level or for the respective partner countries, this can be produced using the data listed below, for example.

Data availability at the pilot area level

The following data is available at pilot area level:

- Bavarian hazard information map
- Protective forest mapping according to Art. 10 BayWaldG
- Forest function mapping according to Art. 6 BayWaldG

Steps for calculating the indicators for mapping

In addition to the area evaluation of the protection and functional forest mapping in the Living Lab, the Bavaria-wide reference map of natural hazards from the Bavarian State Office for the Environment provides a further basis for the inventory map of the ecosystem service ‘Protection against natural hazards’, in which the areas of possible hazards from mass movements such as rockfall, rockfall, slope failures or landslides are marked in colour. This can show further areas for the Living Lab in which natural hazards can be minimised by forest stands.

The most important assessment criteria of the natural hazards information map include (LfU 2020):

- Topographical maps that provide information about the nature of the terrain: Roughness, gradient, etc.
- Orthophotos
- Digital terrain model
- Land utilisation

Brief summary of rock and boulder impact methodology:

- All slope areas with an inclination $\geq 45^\circ$ are intersected with the geological map
- Roughness of the area results from terrain forms, e.g. scree slopes
- Attenuation of the subsoil is also taken into account when determining the hazard areas
- Forest cover is indicated by the number of trunks per hectare (coniferous forest: 100 trunks per hectare; deciduous forest: 275 trunks per hectare). A model then calculates a factor for the mean hit distance as a function of the block size with which a trunk of the defined forest type is randomly hit
- A degree of rounding of 81% of the cuboid is assumed
- The size of the blocks is also taken into account, as this has an influence on the contact reaction (small blocks are more strongly influenced by roughness than larger ones)
- Tree hits are factored in using a random variable

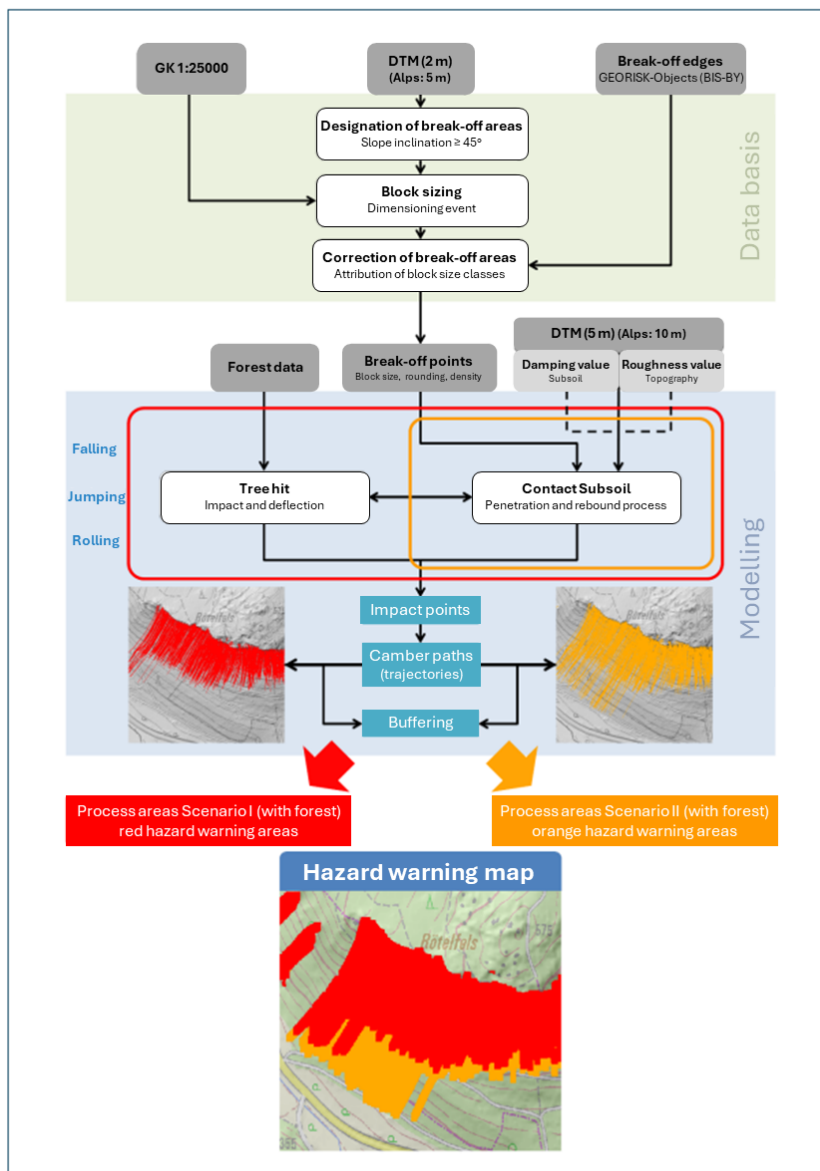


Figure 1: Procedure for the rockfall/blockfall hazard map (LfU 2020) (DTM: Digital Terrain Model)

Brief summary of the methodology for slope failures:

- Slope inclination and geological subsoil are the main factors
- Calculation of the degree of safety (ratio of restraining to driving forces)
- Calculation of the root force in forest areas, as roots lead to greater stability
- Additional calculation of the topo index: information on the topographically determined water saturation potential

3 References

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