InnoForESt

Smart information, governance and business innovations for sustainable supply and payment mechanisms for forest ecosystem services

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D2.2 Mapping of forest ecosystem services and institutional frameworks – Final report

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Abbreviations

CICES	Common International Classification of Ecosystem Services
CS	Civil Society
EC	European Commission
ES	Ecosystem services
FES	Forest ecosystem services
MAES	Mapping and assessment of ecosystem services
NGO	Non-governmental organisation
IRs	Innovation Regions
WP	Work package

Executive summary

Promoting or upscaling governance and business innovations requires an understanding about the conditions and contexts that support a particular innovation. Indeed, context can importantly condition the emergence of new ideas as well as their stabilization and system-level uptake. Ecosystems and the services they provide can be considered this kind of context for innovations because they vary across the landscape. Furthermore, the ways in which ecosystem services (ES) are governed can importantly condition the emergence and up-take of new ideas. These institutional, structural and procedural conditions vary across different administrative units, for example countries or regions. As both ecological and institutional context matters for innovations in the forest sector, we capture these variations and provide a basis for a more context-relevant analysis of innovation evolution, which potentially supports replication and upscaling of innovations. In general, there is a good spatial understanding of Europe's forest ecosystem services (FES) but ecosystem service supply and demand have been matched only as rough estimates of scarcity. What is missing so far is a thorough analysis of the societal demand for FES, as expressed in policy, and the combination of biophysical and institutional mapping.

We propose that societal demand can be derived from formal goals and argumentation in public strategies and laws, as these are the results of processes engaging societal actors and expertise. In the past years, several European policies have gradually taken up the notion of ES, and the European Forest Strategy fares well in its reference and integration of ES. However, what is missing is an analysis of the extent and the ways in which national forest related policies recognise FES and how this recognition coincides with ecosystem service supply at the spatial scale. By analysing how different EU, national and regional policies address forest ecosystem service relevant innovations, governance mechanisms and actors, we develop a deeper understanding of the biophysical-institutional landscape that can condition innovation in the forest sector. Based on our biophysical and institutional mapping, InnoForESt can identify niche innovations and their transferability, upscaling and further co-learning in comparable high potential context regions.

This report describes the justification for mapping specific FES and policies and reports the methods applied in conducting the biophysical and institutional mapping as well as the findings. The report is supplemented by a coarse level map interface that can be used to visually analyse the coincidence of biophysical FES supply and institutional FES demand, innovations and governance, as expressed in forest strategies.

The **biophysical mapping** of FES conducted for this report focused on the supply of ES and relied on simple mapping methods. The mapping process followed four main steps: 1) Identification of FES; 2) Definition of the indicators to map the selected FES; 3) Production of Pan-European maps of selected FES, 4) analysis of hotspots, synergies and trade-offs and spatial bundles of FES. Given the European focus of the study, the identification of FES and definition of related indicators built on the CICES classification and the set of MAES indicators. Indicators were then refined based on the availability of adequate spatially-explicit data at the European level. A total of 13 indicators were eventually defined and maps produced for each of these. As maps of FES showed ES supply on a per unit area basis, the potential of a region or a country to provide a given FES requires considering the actual extent of forests in that region or country. The analysis of hotspots, synergies and trade-offs and bundles of FES, which was carried out on a subset of eight FES, allows policy makers to get further insights about FES concentrations and coincidence.

The **institutional mapping** was carried out to identify current and future policy demand for ES. The policy demand was analysed through detailed policy document analysis, for which a protocol and database were developed and iterated among the team. The initial document analysis conducted in 2018 covered the most relevant national or regional forest, biodiversity and bio-economy strategies in the InnoForESt case study areas and at the EU level, altogether 31 policy documents. The document analysis was reported through an online survey that was used to produce a database, with both quantitative grading of weight in the document and qualitative text examples. The document analysis focused on ten FES: wood, bioenergy, non-wood forest products, game, biodiversity conservation, erosion and water protection, climate regulation, resilience, cultural heritage, recreation. Additionally, the analysis considered innovation type and stage, actor responsibilities and rights as well as new governance mechanisms, for all these ten FES.

Our analysis illustrates that both the biophysical distribution of FES and the policy targeting FES differ across Europe. The analysis of biophysical FES supply through bundles shows that biophysical FES tend to be related to the climatic-ecological gradient, with cultural-agricultural FES being concentrated in the Mediterranean area, wood and water FES in the central area, soil carbon FES in the northernmost area and a mix of all FES in the north-eastern area. In terms of demand for FES, our analysis shows that countries do differ in how much weight they place on different FES in their strategies. Wood and bioenergy stand out as the focal FES for both forest and bio-economy policies, while biodiversity conservation is the only FES that is in some form mentioned in all analysed policy documents. The documents identify innovations, actor roles and governance mechanisms in detail for those ecosystem services that they directly address. The analysis of policies shows that biodiversity conservation is supported with innovations. New product ideas are about wood and biomass, sometimes recognising a long value chain. Also networking innovations and market-based rearrangements centre on procurement of raw material, recognising the responsibilities and rights of industry and land-owners. With our analysis combining data on FES provision across the European landscape and document analysis of European forest, biodiversity and bio-economy policies, we show that there is a slight tendency in policies to address and detail innovations and governance for scarce forest ecosystem services.

By analysing how different EU, national and regional policies address different forest relevant innovations, governance mechanisms and actors our analysis provides a deeper understanding of the biophysical-institutional landscape that can condition innovation in the forest sector, and ideally, identify opportunities for transferring and upscaling innovations.

1. Introduction

For centuries the economically identified function of European forests has been timber-production (Farrell et al., 2000). Since the 1990s, minimizing environmental impacts and maximizing co-benefits has received more attention and forest governance has evolved to engage a greater number of stakeholders, shifting away from mere promotion of timber production. In the past years, several European policies have gradually taken up the notion of ecosystem services (Bouwma et al., 2018). In particular, the European Forest Strategy fares well in comparison to other sector policies in its reference and integration of ecosystem services. Today, the integration of the multiple functions into forest governance is challenged by the multiplying demand for more diverse services provision, including climate regulation, risk management, food and energy production and biodiversity conservation (Winkel and Sotirov, 2016; EASAC, 2017). Society's multiple demands on forest ecosystems call for new and innovative ways of governing and generating income from forests more sustainably. To achieve this, the forest sector needs to be more aware of the services that forest ecosystems can offer, more inclusive of different actors and approaches, and more open to new forms of forest governance.

Producing added value from forest ecosystems will have important implications on the rights and responsibilities of those people and organisations that own, manage and use forests, such as private forest owners, companies and states, and their responsibilities to forests. Aiming for a sustainability transformation in the forestry sector, and securing the provision of a broad range of forest ecosystem services (FES), our analysis has three objectives. First, we seek to increase the understanding of FES services supply using spatial analyses at the European scale. Second, we aim to provide an institutional mapping of European forested countries, documenting their policy demand for FES as expressed in policy documents, including innovations, reconfigurations of actors' rights and responsibilities and new governance mechanisms for FES provision. Third, we seek to understand the coincidence of supply and demand of FES across the EU. To address these objectives, we conduct spatially referenced analyses of the biophysical data on forest ecosystem services across Europe and policy documents in a set of forested EU countries (Figure 1).

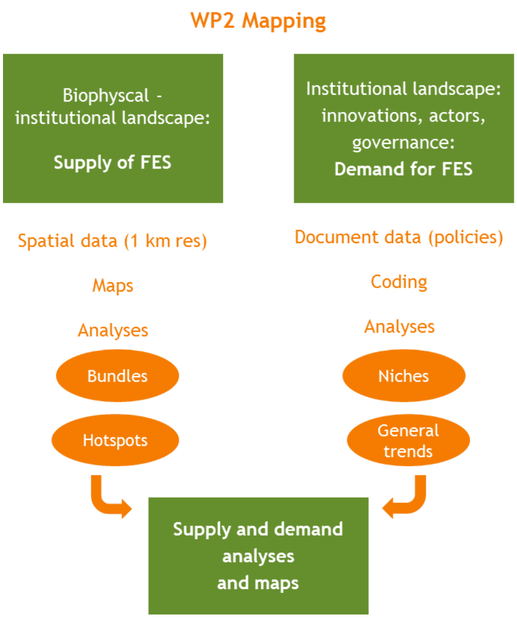

Figure 1. InnoForESt mapping at a glance.

Promoting or upscaling innovations requires an understanding about the conditions and contexts that support a particular and successful innovation. Indeed, context can importantly condition the emergence of new ideas, their stabilization and system-level uptake (Geels 2002; Purkus et al., 2018). Ecosystems and the services they provide can be considered this kind of context for innovations (de Groot et al., 2010; Haines-Young and Potschin, 2011). Furthermore, the ways in which ecosystem services are governed can importantly condition new ideas (Loft et al., 2015; Primmer et al., 2015). However, these biophysical, institutional, structural and procedural conditions vary across the landscape and particularly across different administrative units (Ruhl, 2016). As both ecological and institutional context matters for innovations in the forest sector, we capture these variations and provide a first basis for a more context-relevant analysis of innovation evolution, which potentially spurs new innovations.

In general, there is a good spatial understanding of Europe's forest ecosystem services (Maes et al., 2013), but ecosystem service supply and demand have been matched only as rough estimates of scarcity (Burkhard et al., 2012). What is missing so far is an analysis of the institutional landscape for FES provision and for policy demand for FES. The societal demand could be derived from formal goals and argumentation in public strategies and laws, as these are often the results of processes engaging societal actors and expertise (Hajer and Wagenaar, 2003; Bunea, 2017). By analysing how the EU, national and regional policies address different forest relevant innovations, governance mechanisms and actors, a deeper understanding of the biophysical-institutional landscape that can condition innovation in the forest sector, is developed.

The biophysical and institutional factors chosen for analysis in this WP2 rely largely on the knowledge we had regarding the Innovation Regions (IRs) of InnoForESt at the start of the project. The most central FES for the innovations had been identified at the beginning of the project and especially the institutional factors of the IRs have been refined by stakeholder and governance analysis that the IRs have produced for WPs 4 and 5. All of the factors analysed have been iterated with the other WPs keeping in mind the objective of WP2 to produce a coarse illustration of the socio-ecological and institutional diversity surrounding our Innovation Regions. Generating an overview of the physical and political context in forests in Europe was seen as an important starting point for the project and to work as the basis of more detailed innovation analysis.

This Deliverable is the final report of Work Package 2 of the InnoForESt project (*Smart information, governance and business innovations for sustainable supply and payment mechanisms for forest ecosystem services;* GA no. 763899), following D2.1, which was the first draft report. The objectives of this WP are to a) take stock the social-ecological landscape of Europe, and b) compile the technical and institutional landscape influencing innovations for forest management and ecosystem services provision in form of maps and databases. The D2.1 draft and this report are a basis for supporting other work packages within the InnoForESt project; the detailed analysis of governance factors in WP3 Smart ES governance innovations, the innovation and governance idea cross-feeding in WP4 Innovation platforms for policy and business, and the interactive prototype assessment in WP5 innovation process integration. Based on this work, InnoForESt will identify niche innovations for further co-learning, by analysing the socio-economic and institutional conditions for traditional technological and business innovations, opportunities in the emerging non-timber forest products-based bio-economy (Kleinschmidt et al., 2014) as well as new policy instruments such as Payments for Ecosystem Services (PES) and habitat banking (Primmer et al., 2013; Loft et al., 2015).

This report describes the justification for mapping specific forest ecosystem services and policies and describes the methods applied in conducting the spatial and institutional mapping as well as the initial findings.

The following sections consist of three main parts: 2) Forest ecosystem services mapping, 3) Institutional mapping and 4) Interactions between biophysical and institutional data, each outlining data collection and methods for the respective task, which is followed by an analysis of the data.

2. Biophysical ecosystem services mapping

2.1 Methods and data

Forest ecosystem services maps are a valuable tool to support decisions that may affect the delivery and/or the enjoyment of ES. Indeed, maps of ecosystem services(ES) have been used to identify areas that are crucial for supply, namely the provision of a service by ecosystems; demand, namely the need for a service by society; and flow, namely the mobilization of a service between a producing site and a benefiting site in a given time (Burkhard et al., 2014). Such information is then suggested to be used, for example, to develop sustainable landscape plans, design nature-based solutions, assess the dependence of a region on ES produced elsewhere or estimate the role played by a region in guaranteeing ES to one or more regions. In order for ES maps to convey useful information, they must be based on appropriate ES indicators and be produced according to reliable mapping methods. The same applies in the more focused mapping of FES.

While basic biophysical maps displaying the existence and occurrences of FES as such convey detailed information about the spatial distribution of FES, they are insufficient for informing governance. Indeed, governance would need an understanding of the concentrations of FES as well as synergies and tradeoffs between FES and the coexistence of different FES, to efficiently target governance and management activities. To address this issue, our thorough mapping of FES was complemented with an analysis of hotspots, synergies and tradeoffs, and bundles of FES.

Several mapping methods can be used, from the simplest (e.g. links between ES and land cover) to the more complex (e.g. quantitative regression and modelling combining field and spatial data). One way to navigate through these methods and choose a suitable method is to rely on a tiered approach, by which questions about the understanding of processes (should physical and social processes be thoroughly understood?), the detail of the mapping output (should the map provide rough or detailed information?) and the information required by decision-makers (does the action require information on the system behaviour?) determine whether a basic mapping method (Tier 1), predominantly involving map overlay and direct extraction of ES information from land use/land cover maps, or more advanced methods (Tier 2 and Tier 3), based on increasingly complex modelling, are to be preferred (Grêt-Regamey et al., 2015). The selection of the mapping method is also related to data availability, the cost of generating high-resolution information and the size of the study area, with poorer data availability, higher cost and larger size going hand in hand with lower tier mapping methods.

The biophysical mapping of FES conducted within InnoForESt's WP2 focused on the supply of ES and relied on Tier 1 mapping methods. This latter aspect is consistent with the stock-taking nature of the mapping task, as per project's goals. The mapping process involved two major activities: a basic mapping of a broad list of ecosystem services associated with forest ecosystems and a targeted mapping on a limited set of FES that are strongly linked to forest ecosystems (Figure 2). This latter mapping activity, which resulted in maps all having the same 1-km resolution, dove deeper into the spatial distribution of FES across the EU, delineating areas supplying large amounts of ES (FES hotspots), assessing correlations between ES (FES synergies and trade-offs) and identifying clusters of multiple ES (FES bundles).

Common to both mapping activities is an extensive review of both literature on FES mapping and data available to map FES. Further, the mapping activity relied upon the adoption of a reliable classification scheme for the selection of the FES to map, as described below.

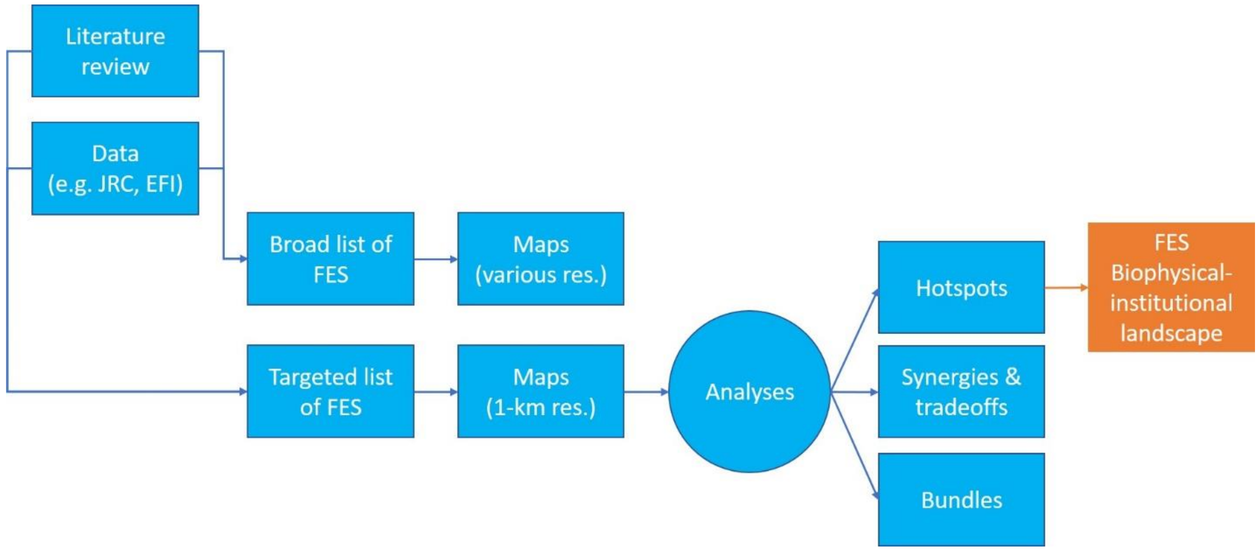

Figure 2. Biophysical mapping at a glance.

The selection of FES that are as explanatory as possible about the range of benefits forests provide to people requires an ES classification that is both comprehensive and widely agreed upon. Building on various classification schemes, such as the Millennium Ecosystem Assessment (MA, 2005) and the Economics of Ecosystems & Biodiversity initiative (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, http://www.cices.eu) has been developed under the coordination of the European Environment Agency (Haines-Young and Potschin, 2013). CICES is used to frame both research and policy and provides a meaningful standardization in the way ES are described. While CICES does not fully consider biodiversity/habitat issues compared to the MA and TEEB, it was preferred to these for being the classification scheme according to which the EU flagship initiative on Mapping and Assessment of Ecosystems and their Services (MAES) was conducted.

CICES classifies ES using a five-level hierarchical structure, where each level is progressively more specific. The five levels are:

- Section: main category of ES (i.e. provisioning, regulation/maintenance, cultural)
- Division: main type of output or process (e.g. nutrition, materials, etc.)
- Group: biological, physical or cultural type or process (e.g. biomass, water, etc.)
- Class: biological or material outputs and bio-physical and cultural process that can be related to service sources (e.g. cultivated crops, bio-remediation by micro-organisms, etc.)
- Class type: individual entities envisaging ways to measure the associated service output (e.g. crops by amount, bio-remediation by amount or type, etc.)

The two mapping activities performed in the framework of WP 2 are thoroughly described in the following sections.

2.1.1 Basic mapping

The basic mapping process followed three main steps

- Identification of FES;
- Definition of the indicators to map the selected FES;
- Production of Pan-European maps.

The fourth step, analysis of hotspots, synergies and trade-offs and spatial bundles of FES was part of the detailed mapping.

2.1.1.1 Identification of FES

The set of FES to be mapped under this task in the InnoForESt project was defined starting from all classes (and class types) listed in the CICES classification scheme, and retaining those representing ES of which the forest biome is a major provider. This iteration included coordination with the institutional mapping analysing European policies. The set was checked for consistency and comprehensiveness against the summary table of FES included in the second report of (MAES) initiative (EC, 2014), which was drafted according to CICES version 4.3. The selected FES for provisioning, regulation/maintenance and cultural ES are presented in the CICES format in Table 1, Table 2 and Table 3, respectively.

Table 1. List of provisioning FES (consistent with CICES version 4.3, http://www.cices.eu).

Division	Group	Class	Class type
Nutrition	Biomass	Wild plants	Plants by amount, type
		Wild animals (game)	Animals, by amount, type
	Water	Surface water for drinking	Amount of water
Materials	Biomass	Wood for direct use or processing	Material by amount and type
Energy	Biomass-based	Bioenergy	By amount, type, source

Table 2. List of regulation/maintenance FES (consistent with CICES version 4.3).

Division	Group	Class	Class type
Mediation of waste, toxics and other nuisance	Mediation by ecosystems	Filtration/sequestration by ecosystems	By amount, type, use, media (land, soil)
Mediation of flows	Mass flows	Mass stabilization and control of erosion rates	By reduction in risk, area protected
	Liquid flows	Water flow regulation/maintenance	By depth, volumes
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	By amount and source
		Habitat maintenance/protection	By amount and source
	Soil formation and compositions	Decomposition and fixing processes	By amount/concentration and source
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentration	By amount, concentration or climate parameter

Table 3. List of cultural FES (consistent with CICES version 4.3).

Division	Group	Class	Class type
Physical and intellectual interactions with biota, ecosystems, and land/seascapes	Physical and experiential interactions	Experiential use of the forest.	By visits/use data, plants, animals, ecosystem type
		Physical use of the forest	By visits/use data, plants, animals, ecosystem type
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic and sacred and/or religious	By use, plants, animals, ecosystem type

2.1.1.2 Definition of indicators

Indicators used to map the selected FES were defined starting from the set of indicators proposed in the second MAES report (EC, 2014), which was refined based on the availability of adequate spatially-explicit data at the European level. In particular, data had to be characterized by large enough spatial coverage (i.e. at least the EU, possibly the entire Europe), reasonably high resolution (e.g. in case of raster maps, a resolution of at least 1 km, possibly 100 m) and free distribution by public agencies (e.g. European Commission). Given the stock-taking nature of the mapping task, and the large extent of the study area, indicators were defined so as to require relatively simple analysis of existing data (Tier 1 mapping).

The indicators were selected to describe the supply of ES, namely the capacity of an area to provide ES within a given time period (Burkhard et al., 2012), rather than the flow or demand, which are addressed more through the document analysis. These biophysical indicators could then be used to generate maps conveying accurate information about which areas are key providers of specific FES in Europe and allowing for the comparison of different areas in terms of their ability to supply important FES. Proposed indicators are presented in Tables 4-6, which also report details about data available to assess them. Cells highlighted in grey present ES of which forests are major/important providers, but for which data were not available.

Table 4. Indicators (and data) proposed to map the supply of provisioning FES.

Division	Group	Class	Indicator (unit[a])	Data (unit[a])	Data type[b]	Data provider
Nutrition	Biomass	Wild plants	Presence of plants and mushrooms (# km^{-2})	Species occurrences (-)	Occurrences	Global Biodiversity Information Facility (www.gbif.org)
		Wild animals (game)	Presence of game species (# km^{-2})	Species occurrences (-)	Occurrences	Global Biodiversity Information Facility (www.gbif.org)
	Water	Surface water for drinking				
Materials	Biomass	Wood for direct use or processing	Forest biomass stock (tons km^{-2})	Above-ground forest living biomass (tons km^{-2})	Raster dataset (1-km)	JRC
			Forest biomass increment (tons ha-	Above-ground woody forest	Raster dataset (1-km)	JRC

			^{1} yr^{-1})	biomass increment (tons ha^{-1} yr^{-1})		
Energy	Biomass-based	Bioenergy	Fraction of forest biomass increment for energy production (tons ha^{-1} yr^{-1})	Above-ground woody forest biomass increment (tons ha^{-1} yr^{-1})	Raster dataset (1-km)	JRC

[a] The (-) symbol is reported when the indicator or data are dimensionless.
[b] Data can be of three types: occurrences (i.e. x and y coordinates), polygon shapefile or raster. In this latter case, resolution is reported in parentheses.

Table 5. Indicators (and data) proposed to map the supply of regulation/maintenance FES.

Division	Group	Class	Indicator (unit[a])	Data (unit[a])	Data type[b]	Provider
Mediation of waste, toxics and other nuisance	Mediation by ecosystems	Filtration/ sequestration by ecosystems	By amount, type, use, media (land, soil)			
Mediation of flows	Mass flows	Mass stabilization and control of erosion rates	Forest on steep slopes (-)	Forest cover (-)	Raster dataset (100-m)	Copernicus (CORINE)
				DEM (m)	Raster dataset (25-m)	EEA (EU-DEM)
			Avoided soil erosion in forested areas (tons yr^{-1})	Avoided soil erosion (tons yr^{-1})	Raster dataset (100-m)	JRC
				Forest cover (-)	Raster dataset (100-m)	Copernicus (CORINE)
	Liquid flows	Water flow regulation/maintenance	Water retention potential (-)	Various datasets (e.g. leaf area index, slope, etc.)	Raster datasets (100-m)	JRC
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Pollination potential	Relative pollination potential (-)	Raster dataset (100-m)	JRC
			Visitation probability in cropland by bees living in forest (%)	Land use (-)	Raster dataset (100-m)	Copernicus (CORINE)
		Habitat maintenance/protection	Forest on Natura 2000 sites (-)	Forest cover (-)	Raster dataset (100-m)	Copernicus (CORINE)
				Natura 2000 (-)	Polygon shapefile	EEA
	Soil formation and compositions	Decomposition and fixing processes	Soil organic matter (g C kg^{-1})	Topsoil organic matter (g C kg^{-1})	Raster dataset (500-m)	JRC
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentration	C storage in forests (tons km^{-2})	Forest above-ground carbon (tons km^{-2})	Raster dataset (1-km)	JRC

[a] The (-) symbol is reported when the indicator or data are dimensionless.
[b] Data can be of three types: occurrences (i.e. x and y coordinates), polygon shapefile or raster. In this latter case, resolution is reported in parentheses.

Table 6. Indicators (and data) proposed to map the supply of cultural FES.

Division	Group	Class	Indicator (unit[a])	Data (unit[a])	Data type[b]	Provider
Physical and intellectual interactions with biota, ecosystems, and land/seascapes	Physical and experiential interactions	Experiential use of the forest	Recreation potential of forests (-)	Recreational Opportunity Spectrum (-)	Raster dataset (100-m)	JRC
		Physical use of the forest				
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic and sacred and/or religious	Forest in and around heritage sites (-)	Forest cover (-)	Raster dataset (100-m)	Copernicus (CORINE)
				Heritage sites (-)	Polygon shapefile	UNESCO

[a] The (-) symbol is reported when the indicator or data are dimensionless.
[b] Data can be of three types: occurrences (i.e. x and y coordinates), polygon shapefile or raster. In this latter case, resolution is reported in parentheses.

2.1.1.3 Production of Pan-European maps

This section describes how maps for each FES were created. The maps were produced on the pan-European scale meaning they cover all European countries.

Presence of plants, mushrooms and game
The maps were intended to provide information about where certain forest-related species can be found, and to quantify the probability of finding them. This was achieved following the method proposed by Schulp et al. (2014b), who mapped the occurrences of various species within a study area and then computed, at each location throughout the study area, the number of occurrences within a radius of 25 km. The analysis focused on a total of fourteen commonly collected and consumed forest-related species, as suggested by Schulp et al. (2014b): seven commonly collected and consumer wild plant species, four mushroom species and three game species (Schulp et al., 2014b; Table 7).

Table 7. List of the fourteen species analysed.

Type	Binomial name	Common name
Wild plant	*Allium ursinum*	Wild garlic
	Cornus mas	European cornel
	Fragaria vesca	Wild strawberry
	Humulus lupulus	Common hop
	Lathyrus tuberosus	Tuberous pea
	Rubus idaeus	Raspberry
	Urtica dioica	Stinging nettle
Mushroom	*Boletus edulis*	Penny bun
	Cantharellus cibarius	Chanterelle
	Lactarius deliciosus	Saffron milk cap
	Pleurotus ostreatus	Oyster mushroom
Game	*Capreolus capreolus*	Roe Deer
	Cervus elaphus	Red deer
	Sus scrofa	Wild boar

Occurrences of all species were extracted from the Global Biodiversity Information Facility (GBIF) database (www.gbif.org) in the form of tables reporting the coordinates of sightings.

Consistent with the approach of Schulp et al. (2014b), occurrences dated before 1990 and/or based on fossils or specimens were disregarded. The density of reported occurrences varies significantly from country to country, being generally high in France, Germany, Scandinavia and the United Kingdom, and very low or zero elsewhere (this is mostly due to the absence of reporting to the database, not the actual absence of the species).

Occurrences in table format were converted into shapefiles and subsequently 1-km raster datasets. Neighbourhood analyses were run on the above-mentioned raster datasets to count the number of occurrences within a 25-km radius around each cell (Schulp et al., 2014). The results of these analyses were finally converted into density maps reporting the number of occurrences per square km. The fourteen resulting maps (i.e. one per species), which have a 1-km resolution, provide detailed information only for countries with a sufficient number of reported occurrences.

Biomass

Biomass was mapped as the above-ground forest living biomass (tons km^{-2}) (Barredo Cano et al., 2012) and forest biomass increment (tons ha^{-1} yr^{-1}) (Busetto et al., 2014) in non-protected areas, namely outside Natura 2000 sites, assuming that wood harvesting is not allowed within those areas. This is in fact a very conservative assumption, as harvesting may be possible within protected areas, provided it does not take place in core areas. However, as policies vary significantly from country to country, and possibly from area to area, the proposed assumption sets a general precautionary vision recognizing the existence of constraints on forest exploitation in protected areas. Both maps have a 1-km resolution.

Bioenergy

The bioenergetic potential of forest ecosystems was estimated as the amount of forest biomass that can be used for energy production according to the following assumptions:

- only the biomass increment is available for exploitation;
- no harvest is allowed in protected areas (i.e. Natura 2000 sites);
- on average, 20% of the forest increment is available for energy production as proposed by Zambelli et al. (2012) and Sacchelli et al. (2013).

As suggested before, the second assumption may not hold everywhere, but it is a precaution intended to recognize that new extraction of woody biomass for energy production may be limited in protected areas (definitely in their core areas). The third assumption is an attempt at setting an average percentage, although the proportion of woody biomass used for bioenergy may be lower or higher depending on the country. The map of biomass increment (tons ha^{-1} yr^{-1}) was obtained from the work of Barredo Cano et al., 2012. The resulting map has a 1-km resolution.

Mass stabilization and control of erosion rates

The soil stabilization service provided by forests was mapped in two ways: a direct one, quantifying the magnitude of the service provided, and an indirect one, recognizing the role played by forests in the stabilization of slopes. The direct approach involved the overlay of a forest cover map and a map reporting avoided soil erosion owing to the presence of vegetation (tons of soil yr^{-1}) as obtained by application of the RUSLE method (JRC, 2010; Guerra et al., 2016). The indirect approach involved the overlay of a forest cover map and a slope map (derived from a DEM) to identify steep areas (e.g. > 15° slope) covered by forest. Both maps have a 100-m resolution.

Water retention potential

The capacity of the forest landscape to regulate water passing through it was mapped using the water retention index developed by the JRC (Maes et al., 2015). This is a dimensionless indicator that takes into account interception by vegetation and the water-holding capacity of the soil, but also the effect of slope and soil sealing.

Pollination potential

The pollination service was mapped as the relative capacity of ecosystems to support crop pollination and the probability that bees living in the forest edge visit nearby cropland.
The first mapping approach was based on the map of relative pollination potential produced by the JRC (Zulian et al., 2013).

The second approach implied a more complex analysis and was partly based on Schulp et al. (2014a). Forest edges were extracted from the CORINE land cover map as forest cells within 100 m from non-forest cells. Visitation probability in cropland was computed by applying the following formula (Schulp et al., 2014a):

$$\text{Visitation probability} = exp(-0.00104 * dist\_forest\_edge)$$

Habitat maintenance/protection

The habitat protection function of forests was mapped by overlaying Natura 2000 sites with forest cover as extracted from the CORINE database. Habitat maintenance and protection occur also outside protected areas, but as the Natura 2000 network is specifically aimed at ensuring the survival of Europe's most valuable species and habitats, we can assume that forests in Natura 2000 sites specifically provide this ES (Birds Directive and the Habitats Directive http://ec.europa.eu/environment/nature/natura2000/index_en.htm). The resulting map has a 100-m resolution.

Soil organic matter

The content of carbon in soils was mapped using predicted topsoil organic carbon content (g C kg^{-1}) estimated by the European Soil Data Centre (ESDAC) of the JRC. The dataset was produced by applying a generalized additive model that considers organic carbon measurements from the LUCAS survey as the dependent variables and slope, land cover, annual accumulated temperature, net primary productivity, etc. as the independent variables (https://data.jrc.ec.europa.eu/dataset/jrc-esdac-86). The resulting map has a 500-m resolution.

Carbon storage

The carbon content of forests has been mapped using data on above-ground carbon content as estimated by the JRC (Barredo et al., 2012). Such estimates were obtained by considering the forest cover map (with distinction between coniferous and broadleaved forest types) and the map of ecological zones (FAO; 2001), and applying a series of conversion factors (i.e. average amount of biomass in forest per ecological zone, ratio of below ground to above ground biomass per ecological zone, carbon fraction of forest biomass) on them. Conversion factors had been derived from the IPCC report on Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The resulting map has a 1-km resolution.

Experiential and recreational use

The experiential and recreational use of the forest, intended as the range of recreational opportunities offered by the forest, was mapped by overlaying the forest map extracted from the CORINE land cover with the map of the Recreational Opportunity Spectrum (ROS) produced by the JRC (Maes, 2010; Paracchini et al., 2014).

ROS estimates the recreation potential of an area by means of two variables: provision of recreational opportunities and proximity to residential areas. As three classes are considered for each variable, ROS encompasses a total of nine classes of recreation potential: low provision - easy accessible (1), low provision – accessible (2), low provision - not accessible (3), medium provision - easy accessible (4), medium provision – accessible (5), medium provision - not accessible (6), high provision - easy accessible (7), high provision – accessible (8), high provision.- not accessible (9). The resulting map has a 100-m resolution.

Symbolic value
The symbolic value of the forest was mapped as the presence of forests in and around cultural and natural heritage sites. The location and shape of natural (i.e. natural areas showing outstanding geological and biological elements/processes and/or elements of exceptional beauty) and mixed (i.e. sites presenting elements of both natural and cultural value) heritage sites were obtained from the UNESCO website (https://whc.unesco.org) as a polygon shapefile. Buffers of 1, 2 and 3 km around heritage sites were created and overlaid with a map of forest cover extracted from the CORINE database. Selected radii (i.e. 1, 2, 3 km) are expected to define reasonable buffer areas for the protection of the heritage sites. Resulting maps have a 1-km resolution.

2.1.2 Detailed mapping

A detailed mapping was conducted to provide accurate information across the European Union (EU) about the supply of a limited set of ES that are strongly linked to forest ecosystems. Further geospatial analyses were conducted on the resulting FES maps to: delineate areas supplying large amounts of FES on a per unit area basis – the so-called hotspots – as these may become the target of conservation interventions (Schröter and Remme, 2016); assess correlations between FES as these may reflect situations in which the provision of one FES is associated with that of other FES (synergy) or the provision of one FES is possible at the expense of other FES (tradeoff) (Raudsepp-Hearne et al., 2010); and identify ensembles of FES that repeatedly occur together – the so-called bundles – as these may reflect unique socio-ecological systems (Dick et al., 2010; Raudsepp-Hearne et al., 2010). The mapping involved the following steps:

- Identification of FES;
- Definition of the indicators to map the selected FES;
- Production of EU maps;
- Delineation of FES hotspots;
- Assessment of correlations between FES;
- Identification of bundles of FES.

2.1.2.1 Identification of FES

The selection of FES was based on the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013), which is the classification scheme adopted by the EU initiative on Mapping and Assessment of Ecosystems and their Services (MAES). FES were selected based on two criteria: strong connection with forest ecosystems (i.e. ES that are mostly provided by forest ecosystems) and availability of high-quality geospatial data to map selected FES over the entire EU. Eventually a total of eight FES were selected, of which two provisioning, five regulating and one cultural, as shown in Table 8.

Table 8. FES selected for the detailed mapping.

Section	Division	Group	ES (Class)
PROVISIONING	Materials	Biomass	Wood
	Nutrition	Water	Water supply
REGULATING	Mediation of flows	Mass flows	Erosion control
	Maintenance of biological conditions	Lifecycle maintenance and habitat protection	Pollination
			Habitat provision
		Soil formation	Soil formation
		Atmospheric composition	Climate regulation
CULTURAL	Physical and intellectual interactions with ecosystems	Physical and experiential interactions	Recreation

2.1.2.2 Definition of the indicators

Indicators were defined according to examples presented in the second MAES report (EC, 2014). Most of the selected indicators were directly based on existing spatially-explicit datasets, the only exception being the indicator selected to map water supply (i.e. water yield), which was estimated using ad hoc modeling (Table 9). Selected indicators were mapped over the EU forested area at a resolution of 1km.

Table 9. Indicators used to map the selected FES.

ES (Class)	Indicator	Unit	Reference[a]
Wood	Growing stock volume	m^3 ha^{-1}	Santoro et al., 2018
Water supply	Water yield	mm yr^{-1}	-
Erosion control	Avoided soil erosion	tons ha^{-1} yr^{-1}	Maes et al., 2015; Guerra et al., 2016
Pollination	Relative pollination potential	-	Zulian et al., 2013
Habitat provision	Relative bird species richness	%	Vallecillo et al., 2016
Soil formation	Soil organic carbon	tons ha^{-1}	Hiederer and Köchy, 2012
Climate regulation	Carbon storage	tons ha^{-1}	de Rigo et al., 2013; Barredo et al., 2012
Recreation	Recreation opportunity	-	Paracchini et al., 2014

2.1.2.3 Production of EU maps

Wood

The supply of wood was measured as growing stock volume, which was mapped relying on a dataset produced by the GlobBiomass project (Santoro et al., 2018). The dataset considers growing stock volume to be the volume of all living trees with a diameter breast height larger than 10 cm.

Water supply
The supply of freshwater was estimated as the amount of water running off a land parcel because of the effect of precipitation and evapotranspiration, using the Annual Water Yield model of InVEST 3.3 (Integrated Valuation of Ecosystem Services and Trade-offs).

Erosion control
The capacity of forests to limit erosion was mapped using a dataset created by the JRC that measures the amount of soil that is not lost annually because of vegetation (Maes et al., 2015; Guerra et al., 2016).

Pollination
Pollination, to which forest edges contribute hosting wild pollinator insects, was mapped using the JRC's map of Relative Pollination Potential (RPP) (Zulian et al., 2013). The RPP is a non-dimensional index varying from 0 to 1 that combines information on floral resources, foraging ranges, nesting sites, climate and elevation.

Habitat provision
The habitat role of forests was mapped using the habitat quality dataset produced by JRC (Vallecillo et al., 2016). This dataset reports values of relative bird species richness, intended as the ratio between richness at a location and average richness in a radius of 250 around the location. As the dataset is provided at a 10km resolution, a resampling was done to bring it to a 1km resolution.

Soil formation
Soil formation was measured considering the content of organic carbon in the topsoil and subsoil, which was mapped using data from the Harmonised World Soil Database (Hiederer and Köchy, 2012).

Climate regulation
The climate regulation role of forests was measured considering the amount of carbon they store both above- and below-ground, as reported in a dataset produced by the JRC (de Rigo et al., 2013).

Recreation
The recreational value of forests was assessed through a reclassification of the JRC's map of Recreation Opportunity Spectrum (ROS) (Paracchini et al., 2014), which assigns each 100m x 100m land parcel one of 9 levels reflecting its recreation potential (low, medium, high) and accessibility (low, medium, high). In particular, the recreational value was assumed to be proportional to the product of the potential variable, where low, medium and high potential are equal to 1, 2 and 3, respectively, and the accessibility variable, where low, medium and high accessibility are equal to 1, 2 and 3, respectively. A neighbourhood operation assigning each pixel the mean of values within a 1000m radius and a resampling were performed to obtain a continuous map with a resolution of 1km.

2.1.2.4 Delineation of FES hotspots
Hotspots of single FES, namely land parcels supplying large amounts of specific FES on a per unit area basis, were delineated from the relevant maps as the 20% of forest pixels with the highest supply values. A map of multiple hotspots was also generated by summing up the maps of single hotspots, which had been previously turned into binary maps with values of 1 assigned to hotspot pixels and 0 to non-hotspot pixels. Such hotspot maps are then expected to shed a light upon areas that, given their crucial FES supplying value, may be the target of conservation actions.

2.1.2.5 Assessment of correlations between FES

Pairwise correlations among all FES indicators were tested whereby a positive correlation would reveal a synergy and a negative correlation a trade-off (Geneletti et al., 2018). FES indicators were sampled at 70,000 random locations and the degree of association was measured using the Spearman index.

2.1.2.6 Identification of bundles of FES

Spatial bundles of FES, namely ensembles of FES repeatedly occurring together across the study area, were identified through cluster analysis, which was run on principal components (instead of raw indicators) as these are uncorrelated (Plieninger et al., 2013). The ideal number of clusters (bundles) was determined qualitatively observing the relative importance of the various FES within each bundle and differences between bundles. Such clusters, or bundles, may then provide valuable information about different socio-ecological systems across Europe and say something about the (ir)replaceability of different areas in terms of their ability to supply unique combinations of FES.

2.2 Results of the biophysical mapping

European forests are mapped in Figure 3 as classes 311 (broad-leaved forest), 312 (coniferous forest) and 313 (mixed forest) of the CORINE database. The map highlights how Scandinavian Countries (particularly Sweden and Finland), Baltic countries, the Pyrenees, the Alps and the Carpathians host the largest extents of continuous forest cover. As maps of FES presented below report ES supply on a per unit area basis (e.g. tons km^{-2}), the potential of a region or a country to provide a given FES can only be estimated by considering the actual extent of forests in that region or country according to Figure 3. Considerations about forest extent are particularly useful to avoid interpretation errors when per unit area FES supply is higher in regions characterized by scattered forest cover than it is in regions characterized by large continuous forests, e.g. when per unit area ES supply is inversely related to latitude or altitude. Northern areas and areas at high elevation have more forest cover but less volume and growth. The combined analysis of per unit area FES supply and forest cover as reported in Figure 3 may also help detect areas where the provision of FES is scarce and provision per unit might be more valuable because of this scarcity, or areas where intense forest fragmentation may threaten the provision of FES in the medium to long run. Figure 3 allows also the detection of areas of large extents of forest cover, which can be meaningful for the provision of some FES. In particular, some species depend on large non-fragmented areas of forest, but also other FES such as carbon storage, water regulation or recreation can benefit from continuous forested areas tracts.

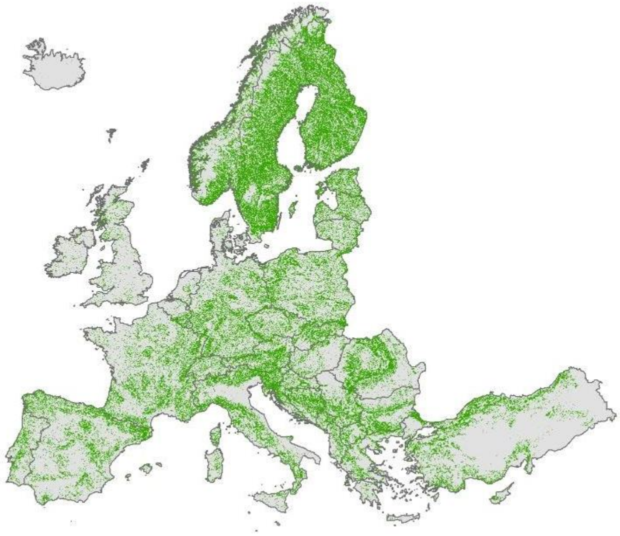

Figure 3. European forests (classes 311, 312 and 313 of the CORINE database).

Basic mapping

An example of the maps produced to show the supply of wild forest plants in Europe is presented in Figure 4, which depicts the density of occurrences of *Fragaria vesca* (Wild strawberry) (countries with scarce or missing data are shown in grey). As stated in section 2.1.1.3, data were not available for all countries, resulting in total or partial lack of information for Southern and Eastern Europe. Supply hotspots could be recognised in Northern France, Scotland and Western England and the South of Sweden and Finland.

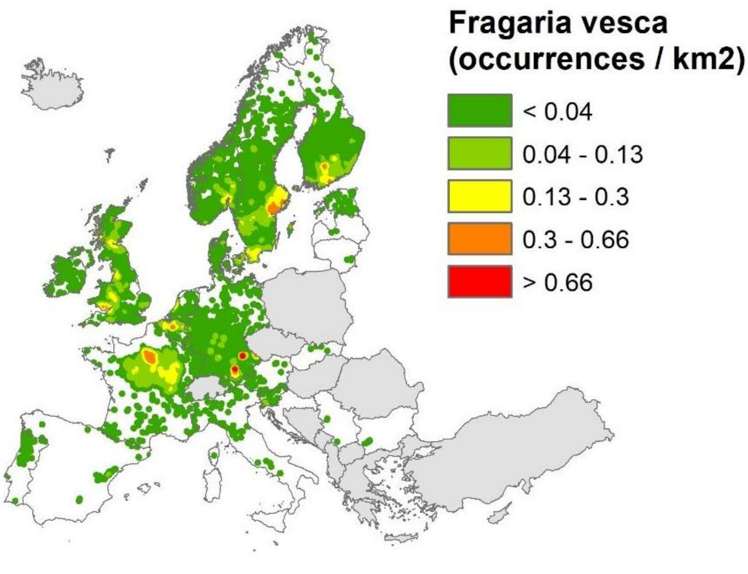

Figure 4. Density of occurrences (occurrences km-2) of Fragaria vesca (Wild strawberry).

An example of the maps produced to show the supply of wild mushrooms in Europe is presented in Figure 5, which depicts the density of occurrences of *Boletus edulis* (Penny bun) (countries with scarce or missing data are shown in grey). Data were essentially missing or scarce everywhere, except in Germany, UK and Scandinavia. Yet this map can provide some initial ideas for innovations or policy orientation. Supply hotspots in this case appeared in Denmark and Southern Sweden, as well as Scotland and Southern England.

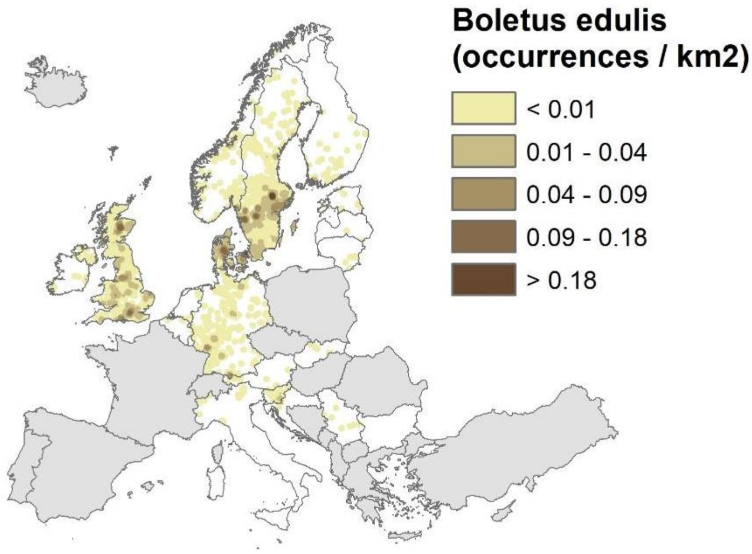

Figure 5. Density of occurrences (occurrences km-2) of *Boletus edulis* (Penny bun).

An example of the maps produced to show the supply of game species in Europe is presented in Figure 6, which depicts the density of occurrences of *Sus scrofa* (Wild boar) (countries with scarce or missing data are shown in grey). Data were mostly available for Spain, Germany and Sweden, and hotspots of supply appeared in small parts of these countries.

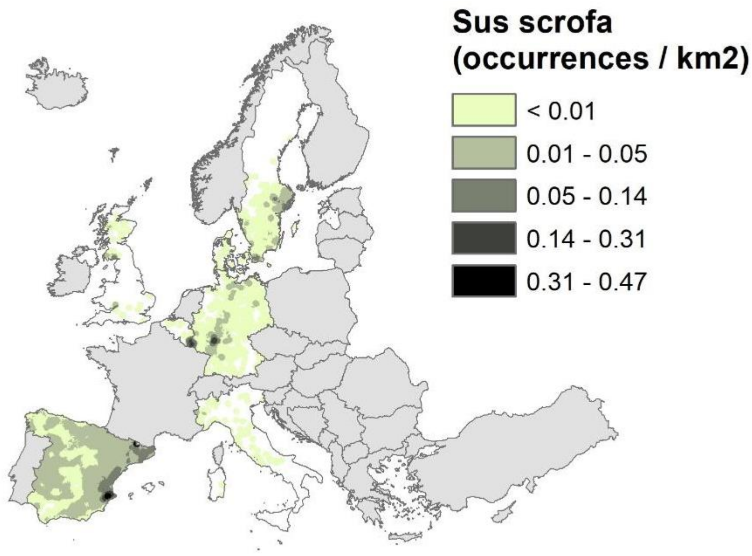

Figure 6. Density of occurrences (occurrences km-2) of *Sus scrofa* (Wild boar).

The overall biomass content of European forests is mapped in Figure 7, showing the amount of above-ground forest living biomass per unit area (tons km^{-2}) outside Natura 2000 sites. The map shows that areas supplying the highest amounts of biomass per unit area (> 15,000 tons km^{-2}) are scattered across Central, South central and Eastern Europe, particularly in Germany, Austria, Poland, Croatia and Romania. Areas characterized by mid to high supply of biomass (10,000 – 15,000 tons km^{-2}) are Southern France, the Alps, the Apennines in Italy, the Eastern Balkans, Southern Sweden, Baltic countries and Northern Turkey. Central and Western Balkans, and particularly Central Sweden and Finland present very large extensions of forests in the medium and low classes of per unit area biomass supply.

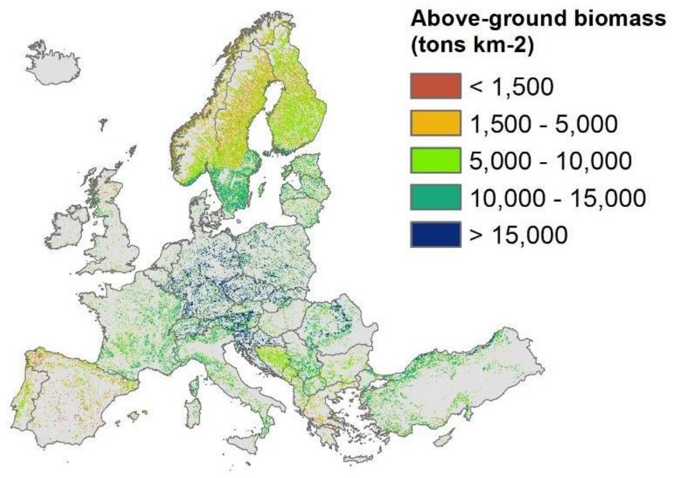

Figure 7. Above-ground forest living biomass outside Natura 2000 sites (tons km-2).

The potential for biomass production is mapped in Figure 8, which shows forest biomass increment (tons ha^{-1} yr^{-1}) in European forests excluding Natura 2000 sites. In general, per unit area biomass increment tends to be higher in temperate areas and lower in boreal areas. Both latitude and elevation contribute to this outcome, as emphasized by lower values in Northern Scandinavia and the Alps. The vast majority of European forests increase their biomass content by 3 to 5 tons per hectare per year, whereas Northern Scandinavian forests mostly fall in the 1-3 tons per hectare and year range.

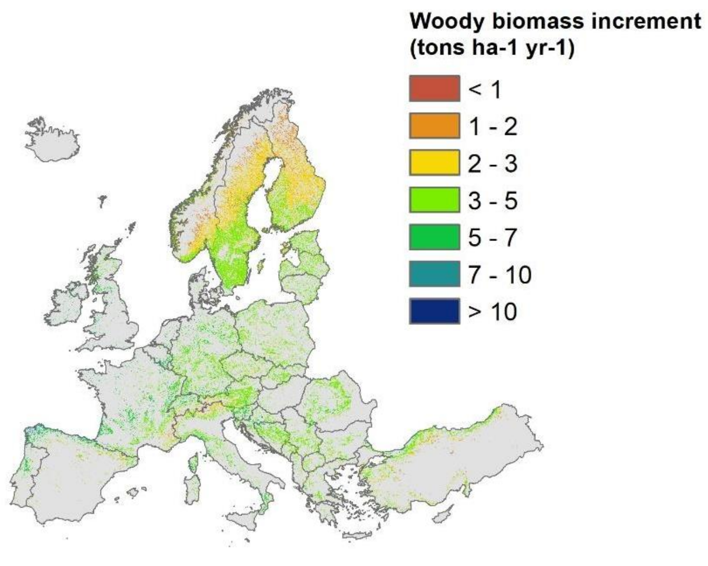

Figure 8. Forest biomass increment (tons ha-1 yr-1) in European forests outside Natura 2000 sites.

The amount of biomass increment that can be devoted to energy production (tons ha^{-1} yr^{-1}) is mapped in Figure 9. Regions having the highest bioenergy potential per unit area (more than 1 ton of biomass per hectare per year) are: Northern Spain, Southern Italy, Central France, Southern Belgium, Switzerland and Southern Germany and Slovenia. Overall, given the extent of their forested areas, Scandinavia (particularly Sweden and Finland), the Baltic countries, Germany, Poland, Austria, Slovakia, Czech Republic and Bosnia-Herzegovina are the greatest reservoir of timber for energy production.

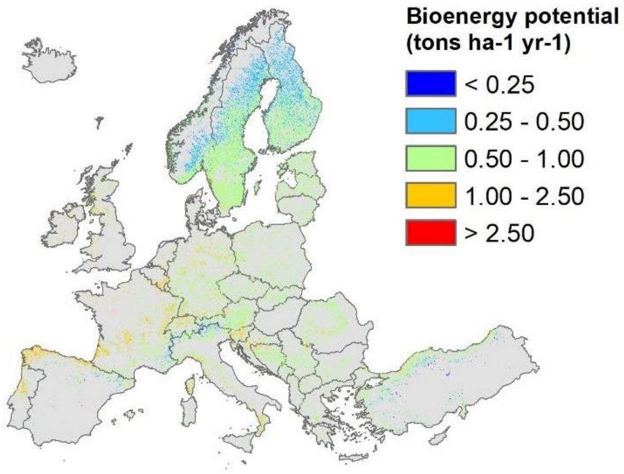

Figure 9. Potential for bioenergy production expressed as a percentage of forest biomass increment (tons ha-1 yr-1).

The mass stabilization service of forests is mapped in Figure 10, which shows forests on slopes steeper than 15 degrees. As expected, the service is predominantly supplied in the big European mountain ranges: the Pyrenees, the Alps, the Apennines, the Balkans, the Carpathian Mountains.

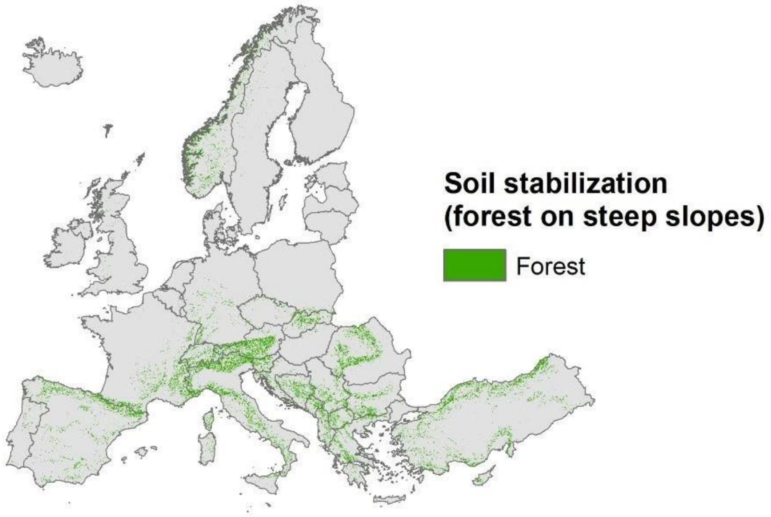

Figure 10. Forest on slopes steeper than 15 degrees.

The relative ability of forests to retain water is presented in Figure 11, which shows the Water Retention Index for European forested areas. Values are higher where the water holding capacity of soil and slope are higher, hence in mountain areas and central-northern forests. In particular, the retention potential is very high in the Apennines, the Carpathians, part of the Alps, Poland, the Baltic Republics and Northern Finland.

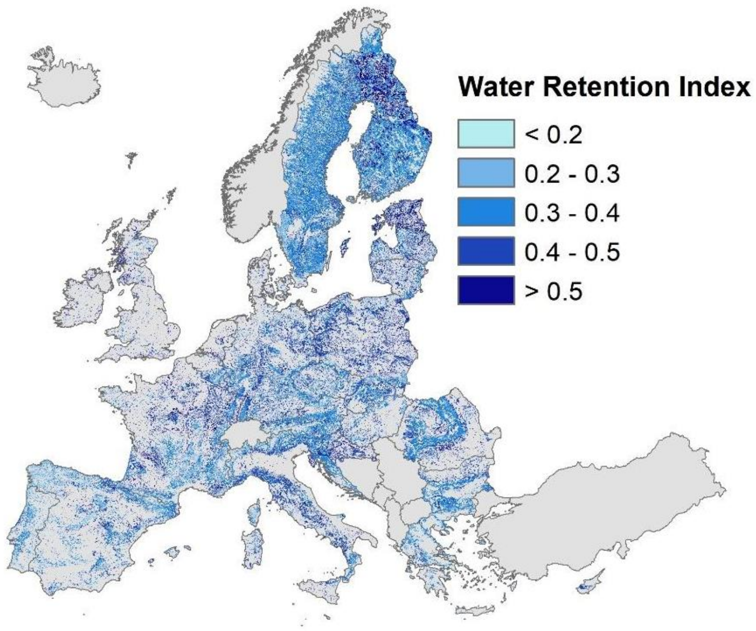

Figure 11. Water Retention Index on European forested areas.

The ability of forests to support wild pollinator insects is mapped in Figure 12, which shows the Relative Pollination Potential (RPP) of forested areas. As forest edges, rather than forest cores, constitute the most suitable habitat for pollinators, the value of the RPP index is particularly high in heavily fragmented forests, where the density of edges is very high. In general, forests in South-central Europe have the highest potential to support pollinator insects.

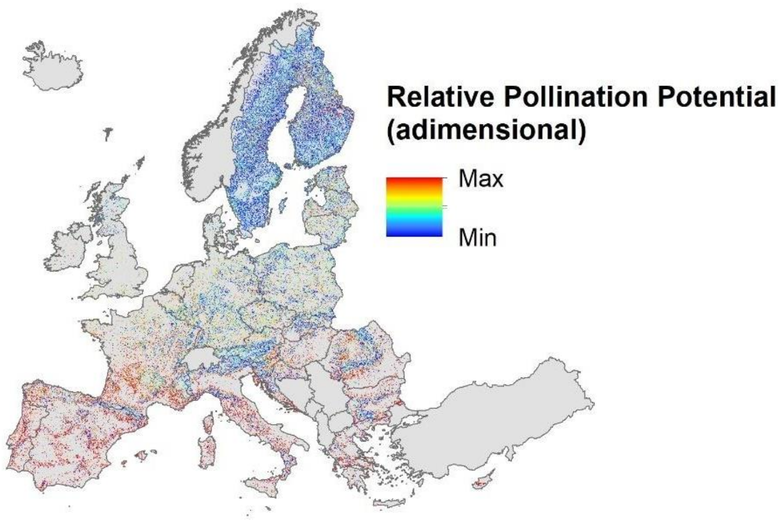

Figure 12. Relative Pollination Potential of European forests.

A flipped perspective on the role of forests in pollination is presented in Figure 13, which shows the probability that pollinator insects relying on forest edge habitat visit nearby cropland. The largest concentration of areas characterized by high visitation probability (> 50%) is found in regions hosting a mix of forests and cropland so that the distance between the two elements is hardly considerable. This is the case of central Europe and the Baltic countries. Flat or semi-flat areas adjacent to hilly and mountainous terrain covered by forests (e.g. along the Italian Apennines) also show high visitation probabilities. On the contrary, large agricultural areas (e.g. Northern France, the Netherlands, Denmark) present very low values (< 25%).

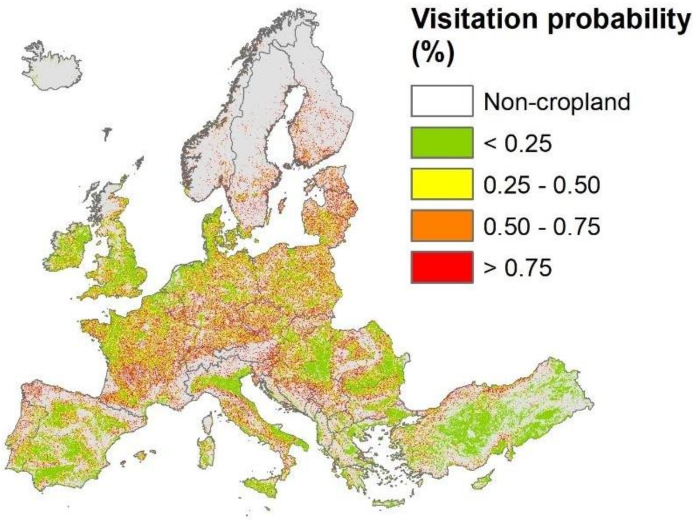

Figure 13 Probability of cropland visitation by pollinator insects relying on forest edges as habitat.

The habitat provision service of forest is mapped in Figure 14, which shows the extent of forest cover within the boundaries of Natura 2000 sites. The hotspots of habitat protection are found in Eastern Europe, particularly Poland, Slovakia, Romania, Slovenia, Croatia, and Northern Scandinavia. Moreover, particularly Finland, Germany, France, Spain and Italy have comprehensively large but more fragmented protected forests, whereas the British Isles have relatively few and small protected forests.

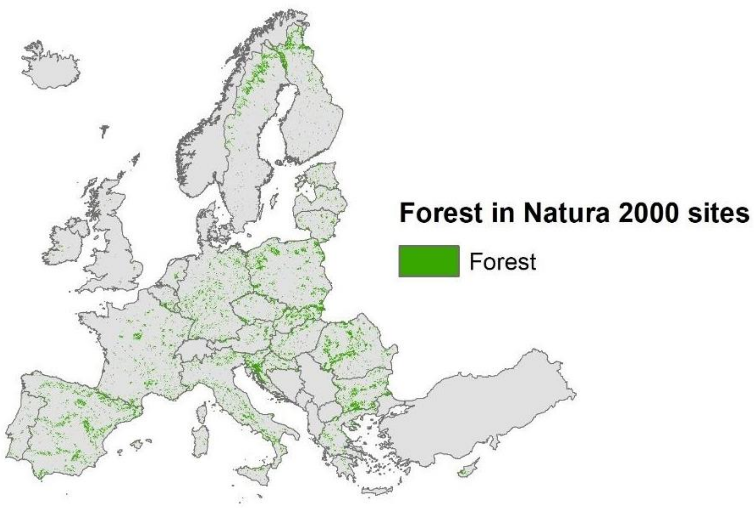

Figure 14. Habitat provision as forest cover in Natura 2000 sites.

The ability of forests to store carbon is mapped in Figure 15 as topsoil organic carbon (g C kg^{-1}) in forested areas (data only available for areas with elevation lower than 1000 m). While the data are not available for Norway, Switzerland and part of Eastern Europe, it is evident that the highest concentrations of soil organic carbon (> 100 g C kg^{-1}) is found in North European forests: particularly in Sweden and Finland, but also in the Baltic countries and Scotland. In the northern peatland areas, carbon is stored also in layers lower than the topsoil. German, Austrian and central European forests in general are in the 50-100 g C kg^{-1}, whereas other forests are predominantly in the 25-50 range.

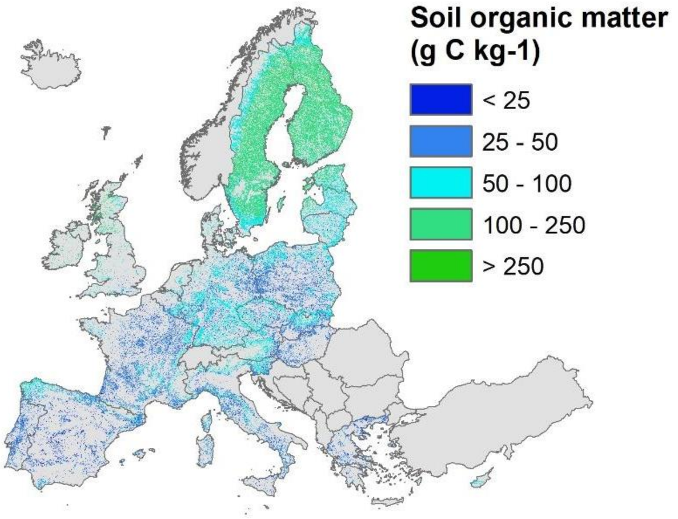

Figure 15. Topsoil organic carbon (g C kg-1) in forested areas below 1000 meters of elevation.

The amount of above-ground carbon stored in forests is mapped in Figure 16. As estimates for this variable were derived from above-ground living forest biomass by application of conversion factors varying little across ecological zones, patterns in the map reflect those visible in Figure 16. Highest values per unit area (> 8000 tons km^{-2}) are found in Germany, Austria, Slovenia, Croatia and the Carpathian Mountains. Southern France, Germany, Poland, Baltic countries and, most of all, Southern Sweden present large areas characterized by medium to high values (6000-8000 tons km^{-2}).

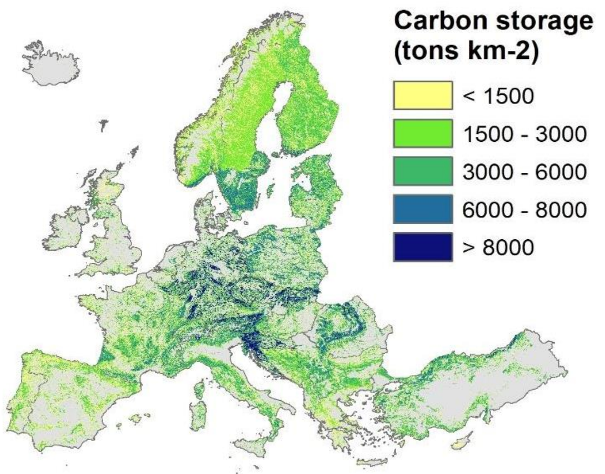

Figure 16. Above-ground carbon stored in forests (tons km-2).

The range of recreational opportunities offered by forests is presented in Figure 17, which shows the Recreational Opportunity Spectrum (ROS) of forested areas. The vast majority of European forests provide a wide range of recreational opportunities within easy reach from urban areas (categories 4 and 7). Forests in Northern Scandinavia and the Carpathians, as well as (to a lower extent) in Spain, Greece and Austria provide exceptional opportunities too, but are hardly accessible because of their remote locations, the ruggedness of the terrain or the presence of poorly extended road networks.

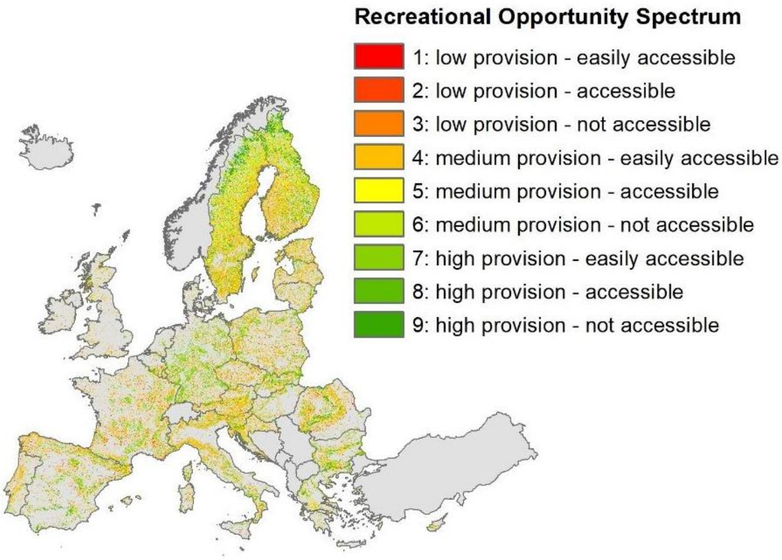

Figure 17. Recreational Opportunity Spectrum (ROS) of European forests.

The symbolic value of forests is mapped in Figure 18 as the presence of forests within, and in a radius of 3 km around, natural and mixed UNESCO World Heritage Sites. The most evident sites are the Dolomites in Italy, the Plitvice Lakes National Park in Croatia, the Durmitor National Park in Montenegro, the Caves of Aggtelek Karst and the Beech Forest of the Carpathians in Slovakia, the High Coast/Kvarken Archipelago in Central Sweden and the Lapponian area in Northern Sweden.

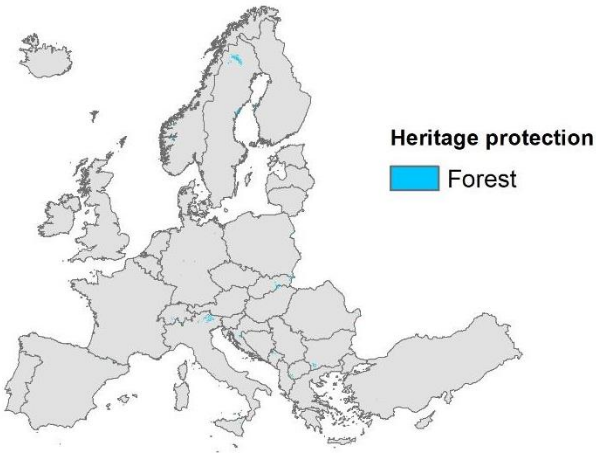

Figure 18. Forest within and around (3-km buffer) natural and mixed UNESCO World Heritage Sites.

Detailed mapping

FES hotspots are reported in green in Figure 19. The hotspot of wood provision is found in the big mountain ranges and at mid latitudes, particularly in France, Germany, Austria, Poland, Czechia and Slovakia. Water supply is particularly strong in the Pyrenees, north-western Spain, the Alps and Western Sweden. Forests play a major role in controlling erosion in mountain areas. Pollination potential is high where forest patches and crop fields are interspersed, particularly in France and Southern Europe.

Forests provide habitat to large proportions of bird species in Central Spain, Southern France, the Apennines, the Eastern Alps, Central Germany and Northern Scandinavia. The soil formation service is greatly supported in Scandinavia and Scotland where soils contain remarkably high amounts of organic carbon. Forests storing the largest amounts of carbon on a per unit area basis are predominantly found at mid latitudes. High recreational values are particularly associated with mountain areas, but also forest landscapes in France and Germany.

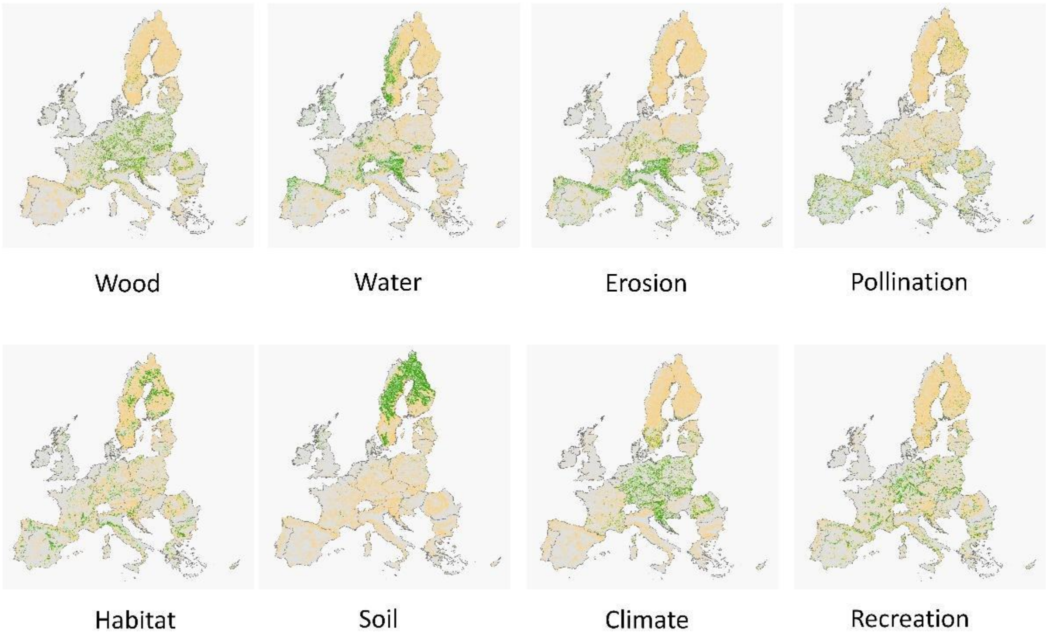

Figure 19. Hotspots of the eight FES considered in the detailed mapping.

Table 10 shows how much of a country's forests is a hotspot of the 8 FES. All countries have more than one fifth of their forests that is a hotspot of one service and most of them included hotspots of five and more services. Belgium, France, Germany, Hungary, Poland and Sweden include hotspots of all FES.

Table 10. Share of a country's forests that is a hotspot of the various FES.

	Share of national forest (%)							
	Provisioning		Regulating					Cultural
	Wood	Water supply	Erosion control	Pollination	Habitat provision	Soil formation	Climate regulation	Recreation
Austria	54.1	79.3	64.3	11.5	7.8	0.1	55.3	8.8
Belgium	47.6	62.0	14.7	15.2	22.6	0.7	45.8	30.7
Bulgaria	16.3	1.7	22.4	32.9	38.0	0.0	0.1	37.8
Croatia	29.3	44.1	45.9	32.5	3.2	0.1	73.8	14.2
Cyprus	0.1	0.7	32.9	52.9	53.4	0.0	0.0	28.2
Czechia	48.0	13.2	23.5	14.2	19.6	0.2	68.2	20.0
Denmark	19.8	16.1	0.0	6.0	18.1	0.4	19.8	11.3
Estonia	7.2	1.2	0.0	15.6	7.1	18.9	3.2	9.1
Finland	0.1	2.0	0.0	9.1	25.7	66.0	0.6	5.9
France	28.1	25.4	25.7	37.4	21.4	1.0	14.0	29.8
Germany	53.6	23.9	19.5	9.3	18.1	2.1	67.0	57.9
Greece	5.3	13.8	24.7	41.2	25.8	0.0	0.0	16.7
Hungary	20.4	2.4	14.2	36.0	9.8	2.6	2.4	29.8
Ireland	20.3	94.0	11.1	18.4	24.1	36.1	0.0	1.2
Italy	21.9	16.9	64.3	39.0	32.3	0.0	0.1	22.9

Latvia	11.9	2.9	0.0	17.3	0.1	4.7	31.7	16.4
Lithuania	30.7	1.8	0.0	9.2	13.9	3.7	9.1	20.9
Luxembourg	42.5	25.8	26.8	14.0	2.0	0.0	32.4	16.7
Malta	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Netherlands	35.4	49.7	0.2	16.0	12.0	4.3	21.0	28.4
Poland	46.9	6.2	6.6	8.9	11.0	4.3	51.3	31.0
Portugal	0.0	31.8	26.9	61.6	23.1	0.0	0.0	14.4
Romania	26.7	11.9	38.1	27.0	14.2	0.1	37.7	14.4
Slovakia	46.2	25.7	61.9	16.3	7.7	0.0	61.6	44.7
Slovenia	48.8	80.2	74.2	24.1	37.1	0.1	84.9	31.9
Spain	3.7	21.4	40.5	52.3	29.8	0.1	0.0	26.6
Sweden	4.0	26.2	1.7	1.8	15.9	50.9	6.9	3.7
UK	54.1	79.3	64.3	11.5	7.8	0.1	55.3	8.8

The number of FES of which forest parcels are a hotspot is summarized in Figure 20. Over 60% of EU forests provide large quantities of one or two FES and approximately 20% of them guarantee major supplies of three or four FES simultaneously. Some forests of Germany, the Alps and the Tatras supply large amounts of five FES simultaneously, and Slovenia hosts forest stands guaranteeing large supplies of six FES.

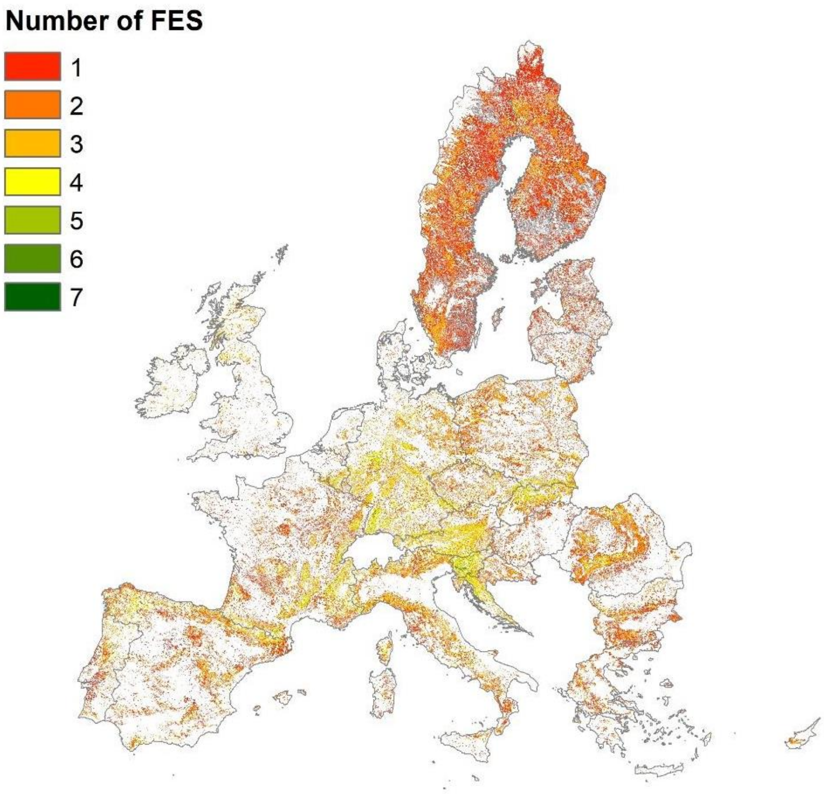

Figure 20. Number of FES of which each forest parcel is a hotspot (i.e. each pixel is assigned a value corresponding to the number of FES of which it is a top supplier). Pixels not being a hotspot of any FES are shown in grey

The correlation analysis showed that a strong synergy exists between wood and climate regulation, while there is a marked trade-off between erosion control and soil formation. A weaker synergy was observed between climate regulation and recreation. Moderate trade-offs characterize the association between pollination and soil formation, and between soil formation and climate regulation.

A total of four clearly distinct FES spatial bundles are observed in the EU that reflect ecological and management conditions (Figure 19). The first bundle, which is called here “Multifunctional”, is characterized by a strong supply of wood, habitat, soil formation, climate regulation and recreation opportunities, and primarily occurs in the North-Eastern part of the continent. The second bundle, which is called here “Wood & water”, is characterized by a very strong supply of wood, water, erosion control and climate regulation, and occurs in mountain regions and central Europe. The third bundle, which is called here “Soil carbon”, is characterized by a very strong supply of soil formation and occurs in the North. The fourth bundle, which is called here “Rural-recreational”, is characterized by a strong supply of pollination and is mostly found in the non-mountainous part of Southern Europe.

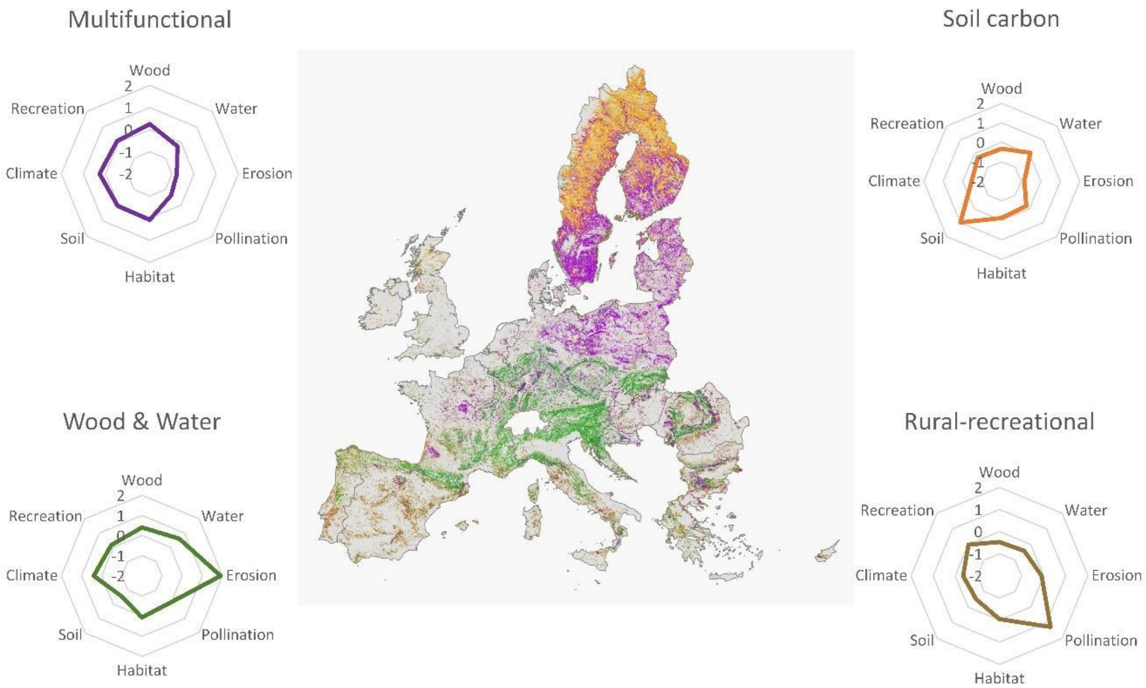

Figure 21. Spatial bundles and their characterization in terms of average supply of the different FES with respect to the EU average.

3. Institutional mapping

Institutional mapping was carried out to identify future societal demand for FES, as formalised and expressed in policy, i.e., policy demand. The aim of institutional mapping was to capture context specific and relatively dynamic policies, which reflect national or regional priorities and tackle new emerging themes, such as ecosystem services, innovations or new governance mechanisms.

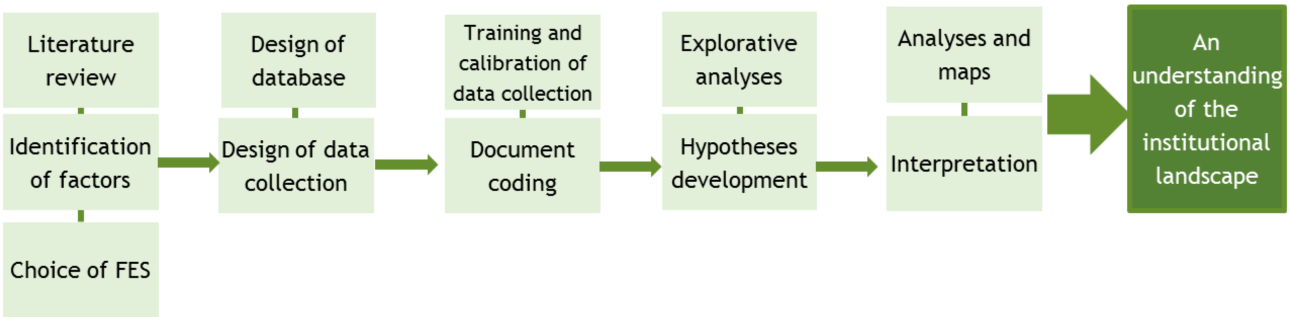

Figure 22. Institutional mapping at a glance.

As a first step, we conducted a quick scan of academic and grey literature on existing comparisons of forest and FES relevant policy documents and forest management systems to organise the development of the database and determine the appropriate data sources (e.g., Hauck et al., 2013; Newig and Fritsch, 2014; Forest Europe, 2015; Harrinkari et al., 2016; Winkel and Sotirov, 2016; Bouwma et al., 2018; EASAC, 2017; Ludvig et al., 2018). In the second step, we conducted a scan of the available types of policy documents that European countries have and the entities responsible for them. We found that almost all European countries have a National Forest Programme (NFP) or in the case of countries with federal structures, such as Italy and Germany, a similar policy process on the federal state level. In the InnoForESt Innovation Regions (IR) (Austria, Czech Republic, Finland, Germany, Italy, Slovakia and Sweden), the programmes are generally entitled forest policies or strategies and endorsed by national ministries or federal governments (FOREST EUROPE 2015).

We then proceeded to delineate the factors that we would analyse and operationalise them with classifications that could potentially be detected in policies. Then we selected the relevant documents developed a protocol for coding the documents. Once the documents were coded, we analysed qualitatively and using simple statistics. Finally, the observations of a subset of the analysed documents, the forest strategies, were reported in maps that could be viewed in an interface alongside the biophysical maps. The data and methods are explained in more detail in chapter 3.2.

3.1 The factors included in the analysis

Forest ecosystem services

Forest ecosystem services showcase the multiple functions of forests: Forests produce wood for raw material and energy and other non-wood forest goods, while also regulating carbon, nutrient and water cycles as well as providing recreation and maintaining a cultural identity (Maes et al., 2013; Saarikoski et al., 2015). Forest policies have addressed multiple forest ecosystem functions and sustainability for several decades (Rammel and van den Bergh, 2003) but the concept of ecosystem services has entered the policy arena more recently (Bouwma et al., 2017).

Table 11. The FES analysed from the policy documents.

Provisioning	Wood
	Bioenergy
	Edible plants and other non-wood forest products: berries, mushrooms, cork, other
	Game
Regulating	Biodiversity conservation
	Erosion and water protection
	Climate regulation, carbon sequestration and stock
	Resilience (risk control and climate change adaptation)
Cultural	Cultural heritage
	Recreation: cultural, physical and experiential interactions

Operationalising forest ecosystem services for the analysis

The ecosystem services analysed were chosen to match the biophysical FES mapping, yet in a way that was realistic to be identified in the policy documents. Also meaningfulness for the Innovation Regions (IRs) was checked after an initial quick analysis of the EU strategies, which were included in the analysis. Of the additions, recreation was central for the case studies while climate regulation and resilience were central in some of the strategy documents. The ten FES analysed in the documents are listed in Table 11. The FES of the institutional analysis indirectly match the FES of the biophysical analysis, i.e. the FES here have been operationalised on the biophysical maps with different indicators for the FES. The FES that were originally identified as most relevant for the IR are reported in Table 12, although as InnoForESt has progressed there have been some changes in what the relevant FES are. For example timber and biodiversity have been recognised as central for all IRs. For the CZR/SK IR non-timber, recreation and spiritual values are central in their innovation.

Table 12. Ecosystem services targeted in the Innovation Regions.

Ecosystem service	Austria	Finland	Germany	Italy	Sweden	CZR/SK
Timber	✓	✓	✓			
Non-timber products			✓			
Carbon			✓			
Climate regulation		✓				✓
Water regulation				✓		
Biodiversity	✓	✓				
Natural hazards protection				✓		
Tourism and recreation	✓			✓	✓	
Spiritual values					✓	

Innovations

For innovation, our analysis sought for new ideas related to forest ecosystem services, building on conceptualisations of technological innovation and innovation systems. Innovation is the development and implementation of new ideas by people who engage in transactions with others within an institutional setting (Van de Ven, 1986).

Laying the basis for our understanding of technological innovation, Schumpter has defined innovation as a continuously occurring implementation of new combinations of means of production (Hagedoorn, 1996). Nelson and Winter (1977), in their institutional analysis, define technological innovation as a non-trivial change in products and processes where there are no previous experiences.

Regarding forest ecosystem services, some of the contextual factors are given and very slow to change; for example, land-use, land-ownership or industry structure, evolve only gradually. Therefore, it is important to be sensitive to changes within these structures, such as emerging or suggested new ecosystem management practices, land-owner collaboration or new business ideas departing from pre-existing operational patterns (Kubeczko et al., 2006). Innovation functions often identified in the analyses of product and process innovations include at least visioning, development and promotion, experimentation and implementation, as well as system-level transition or upscaling (Gopalakrishnan and Damanpour, 1997; Geels and Schot, 2007).

Constructing visions and debating promises is common in innovation processes, where specific characteristics have not stabilized (Konrad, 2006). The hype around an innovation, can be also labelled its promotion (Konrad, 2012), promotion through processes of planning, developing or investing in more extensive R&D, testing and piloting (Kivimaa, 2007; Sengers et al., 2016). Such an innovation stage is likely to be followed by attempts to scale up the innovation, for example, to extend market reach (Naber et al., 2017).

Innovation processes are often categorized by the types of innovations they produce, for example to design, user, product service and governance innovations (Carrillo-Hermosilla et al., 2010). **Product innovations** emerge as a result of targeted design processes or as a response to newly emerging demands or, most commonly, as a result of these two (Nelson and Winter, 1977). Product innovations tend to be linked to **process innovations** but a process innovation might emerge to increase efficiency (Barras, 1990). When an innovation results in the introduction of radically or fundamentally different goods or products, it is initially cost-intensive, which calls for process innovations to reduce cost intensity of those goods and products. For forest ecosystem services, new products could include new medical or cosmetic products or fuels, while process innovation could refer to less invasive harvesting technologies or processing technologies producing less waste. Innovations can occur also in the forms of cooperation among actors relying on forest products and services, i.e**. social and networking innovations**. Social innovation can be defined as changes in attitudes and perceptions of people with shared interests for new and improved ways of collaboration both within the group and externally (Neumeier 2012).This may take place in rural settings (Kluvankova et al., 2017), and include new client and stakeholder engagement processes, forums, working groups or platforms (Han et al., 2013; Kleinschmit et al., 2014) With strong client orientation, the forest sector has also a fast-developing service market on forestry, bio-economy and nature management (Wolf and Primmer, 2009; Mattila et al., 2013; Kleinschmit et al., 2014). **Service innovation** exceeds the use of technology (e.g., Gallouj & Weinstein, 1997; Morrar 2014). In terms of forest ecosystem services, we assume that innovation in services does not only result in products or goods, but also in broader, non-technological outcomes, such as policies or governance mechanisms or novel social and managerial practices. **Market rearrangements and institutional innovation** includes transformations in public and economic institutions, but may also refer to cultural institutions (Davis and North, 1970; Hargrave and Van de Ven, 2006; Weatherley and Lipsky, 1977). Although market rearrangement would require changes in formal rules, the new innovations in FES markets might emerge more informally. Besides changes in market relations with respect to the management of forest ecosystem services, this item may include both perceived changes in traditional practices of forest managers as well as prescribed behavioural changes for public servants in the governmental forestry sector (Primmer, 2011).

Operationalisation of innovations for document analysis
For the analysis of innovation in policy documents, we sought a simple structure in line with framework for the governance of policy and business innovation types and conditions produced by WP3. We anticipated that the policy documents would have little detail on innovations. (Policy innovations could be recorded under governance mechanisms, see p. 30). We distinguished between the stage of the innovation and the type of innovation based on iterations with WP3 (fig. 23). For innovations related to each forest ecosystem service, we recorded from the documents the innovation type and stage, as follows.

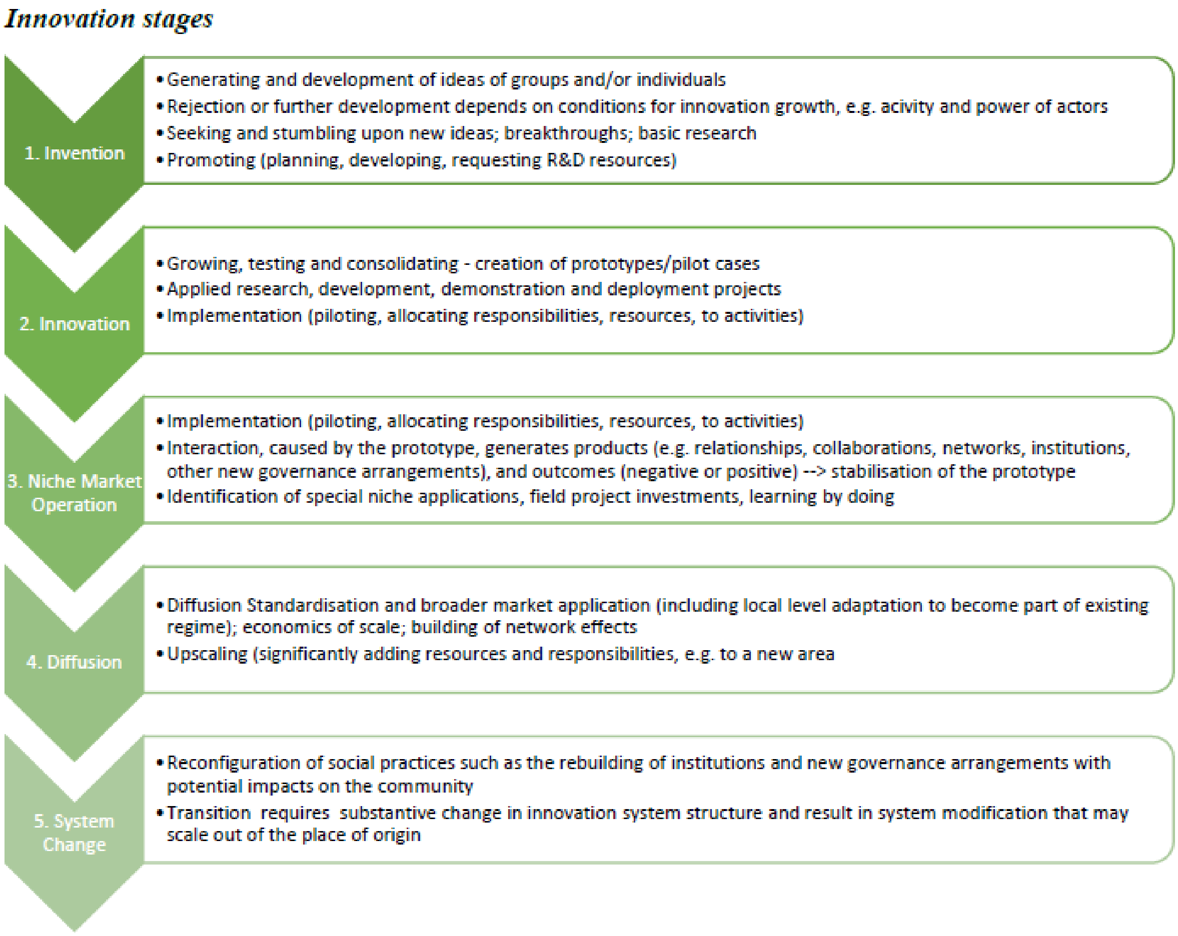

Figure 23. Innovation stages. Source: Innoforests D3.1, own creation/combination; SIMRA - refer to Kluvánkova et al., 2017; Kluvánkova et al 2017; Grubler et al 1999; Christiansen, 2002.

Innovation types used in the institutional analysis

- Product innovation
- Process innovation and technology improvements
- Social process and networking innovation
- Service innovation
- Market rearrangement and institutional innovation

Innovation stages used in the institutional analysis

- No mention
- Visioning (promises)
- Promoting (planning, developing, investing in R&D)

- Implementation (piloting, allocating responsibilities, resources, to activities, consolidation)
- Upscaling (significantly adding resources and responsibilities, e.g., to a new area)

Actors

Forest policies and other policies addressing FES are designed in processes that build on administrative and scientific expertise, and also engage stakeholders in these formal processes. Participatory governance of forests, other natural resources and nature has long been recognized to widen and improve the knowledge-base, onto which policy is designed and to increase the legitimacy of policy through deliberation (Hajer et al., 2003; Primmer and Kyllönen, 2006; Paavola et al., 2009).

Stakeholders taking an active role in designing policy are also assumed to improve commitment and effectiveness of policy and its implementation - but sometimes this involvement results in compromises that dilute policies (Newig and Fritsch, 2009). Actors indeed participate in policy design to represent their own interests (Harrinkari et al., 2016). Some scholars argue that participatory approaches often fail in reflecting issues of elite capture or politics and by not challenging existing power relationships (Bardhan, 2002; Platteau, 2004; Hickey and Mohan, 2005). Indeed, power is often unequally distributed on a horizontal level, i.e., some policy fields or stakeholder groups have more influence than others. The so-called participatory turn has not reached all governance levels and the ownership of policy design and implementation might remain with the authorities (Maier et al., 2017). Designing and implementing FES related policies involves many different actors with often quite heterogeneous interests and asymmetric information. Thus, policies will evidently need to address a broad range of cultural perceptions, values, and socio-economic interests of various stakeholder groups (Hauck et al., 2013; Primmer et al., 2018).

The forest sector has increasingly recognized the need to engage with society in other processes than formal policy processes (Cashore, 2002). The increasing acknowledgement of stakeholders has followed the demands to improve sustainability, both in the global markets and in local operational contexts (Kourula, 2010; Toppinen and Korhonen-Kurki, 2013; Kleinschmit et al., 2014). Because ecosystem services broaden the view of forest functions and the benefits that can be derived from forests, they introduce a broader view to stakeholders and actors relevant for policy (Saarikoski et al., 2015). Actors influencing the use and depending on ecosystem services represent different sectors and different types of actors, which requires cross-sectoral and multi-level collaboration (Primmer and Furman, 2012; Loft et al., 2015).

In Europe, the organisation of forest ownership varies; also the countries that the institutional mapping addresses have different proportions of private and public ownership of forest (Forest Europe, 2015). Beyond forest owners, also other actors benefiting from ecosystem services can also be assumed to hold rights to use or access, or they can seek to gain such rights (Hein et al., 2006; Rinne and Primmer, 2016; Paavola and Primmer, 2019). Indeed, FES often have public good characteristics, and rights to them remain undefined. As rights are often not directly stated, they can be inferred by references to responsibility or ownership, or to access, use, manage or make decisions, even when these are customary (Schlager and Ostrom, 1992). Rights to ecosystem services can be explicitly defined, for example, in laws or decrees, or they can rely on customs, routines, professional norms, or other informal institutions. For this reason, numerous actors can potentially hold or expect to improve their rights to forest ecosystem services.

Table 13. Shares (%) of publicly and privately owned forests in innovation regions and other analysed regions.

	Public %	Private %	Other %
Austria	23	66	11
Czech Republic	77	23	
Denmark	24	76	
Finland	30	70	
France	25	75	
Germany	52	48	
Italy	34	66	
Ireland	53	47	
Netherlands	49	51	
Slovakia	50	40	10
Spain	29	70	
Sweden	24	76	

Source: FOREST EUROPE/UNECE/FAO enquiry on Pan-European quantitative indicators

Operationalisation of actors for document analysis

Policy documents often identify implementation responsibilities, or at least they report the entity that has been responsible for compiling the strategy or other policy document. Much less directly, the documents reflect rights that actor types might be assumed to hold, that the policy aims to strengthen or secure. We sought to identify also mentions of rights.

The section about actors included two questions with the same structure:

19. Actors and their responsibilities in relation to this FES (actor types in detail)
20. Actors and their rights in relation to this FES (actor types generally)
- Public administration
- Forest and wood using business and industry
- Forest related service business
- Associations, NGOS and civil society (CS) actors
- Landowners
- Recreational users
- Citizens
- Educational bodies
- Research institutes
- Financiers

Governance mechanisms

The term "governance" captures both government-driven hierarchical steering based on regulation and broader and more openly engaging policy design and implementation (Wurzel et al., 2013). Thereby, governance depicts a dynamic interaction of actors and institutions (Borrás and Edler, 2012). While policy is seen as operating with a range of instruments resting on differing logics (Howlett, 1991), governance further emphasizes voluntary instruments and cooperative structures. Cooperation is understood to support hierarchical structures opening up, through so-called multi-level governance, cross- sector cooperation through both formal and informal networks, and finally engagement of the private sector, businesses and civil society.

Most often governance implies certain degrees and forms of self-regulation and cooperation among different types of actors and coalitions (Rhodes, 1997; Biermann, 2007). Thereby, environmental governance depends on various formal and informal institutional structures that determine and regulate resource use at different levels and scales of socio-political organization (Berkes, 2002). In dynamic terms, environmental governance may furthermore imply formal and informal institutional development and change dependent on the social-economic-ecological context (cf. Loft et al., 2015; Vatn, 2005).

The expectations for forest ecosystem service innovations are connected to the different governance-mechanisms that are deployed, and the assumptions underlying them (Primmer and Furman, 2012; Primmer et al., 2015). These include hierarchical governance, which can be operationalized through regulation, incentives or information. Ecosystem services are often regulated through natural resource and biodiversity regulation but the emergence of the concept in policies suggests regulation might also be evaluated against the concept (Borgström and Kistenkas, 2014; Bouwma et al., 2018). Securing ecosystem service provision with laws has been suggested to guide green infrastructure and land-use-planning, or as a part of environmental impact assessment and no-net-loss compensation policies (Ruhl et al., 2013; Geneletti 2011; 2015). It is common to expect that learning about the importance of a new societally valued phenomenon would lead to new regulations.

Incentives have been at the centre of ecosystem services policy analysis for long, both as government payments, and as more market-based arrangements (Vatn, 2010; Primmer et al., 2013; Börner et al., 2017). Payments for environmental or ecosystem services (PES) build on ideas of values driving the institutional arrangements and markets forming around recognized non-market benefits, such as biodiversity conservation or water or carbon retention (Wunder et al, 2008). As such, they are relevant governance arrangements for the provision of many FES. Government investments or subsidies can also be allocated using competitive, market-like mechanisms, and they are sometimes termed as PES (Vatn, 2010).

Land-use planning is another governance mechanism strongly promoted by the ecosystem services research community (Potschin and Haines-Young, 2011). The excitement about this idea is connected to new spatial data-driven capacities and modelling but practical applications face both technical and institutional challenges (Primmer and Furman, 2012; Ruhl, 2016).

To complement payments and planning, collaborative-adaptive governance mechanisms are often suggested by analysts and by practitioners (Paavola and Hubacek, 2013; Primmer et al., 2015). The institutional challenges that have been identified in applying participation alongside scientific-technical planning include political agendas, professional norms and competencies, and lack of integration (Primmer and Furman 2012; Saarikoski et al., 2018).

Governance can change radically as a response to societal demand or for reasons that are more political. Indeed, the introduction or dismantling of a policy can be disruptive (Kivimaa and Kern, 2016). These kinds of disruptions are important to recognise when studying innovations. Forest ecosystem service governance might face disruptions, for example, when the policy shifts toward emphasising climate change or bio-economy.

Operationalisation of governance for document analysis
We operationalised the governance approaches with help of following categories:

- Markets (direct private-to-private, private-to-private with intermediaries, market-like arrangements organized by government
- Incentives by government

- Disruption
- Regulation ((other) laws, statutes)
- Collaborative (networks, cooperatives)
- Information (guidelines, information technology and platforms, extension and advice
- Clearly new governance mechanisms related to this FES mentioned in the document.

3.2 Methods and data

Mapping through document analysis

The documents analysed were chosen based on their availability and relevance for forest management and forest ecosystem services. Forest strategies were anticipated to reflect policy demand for forest ecosystem services and governance and business innovations in a context-specific and dynamic fashion because they address policy in the medium term (often 10 years). Generating demand for uses of forests other than timber production, we chose to analyse biodiversity strategies and bio-economy strategies. We also considered rural strategies or strategies highlighting green infrastructure and recreation but the different countries and regions did not appear to have a uniform set of such strategies. All Innovation Regions were requested to analyse at least the three following documents:

- National or regional forest strategy
- National or regional biodiversity strategy
- National or regional bio-economy strategy

The mapping was conducted in 2018 and 2019 through document analysis of the forest strategies, biodiversity strategies and bio-economy strategies for the Innovation Region countries and the EU as well as forest strategies of four additional countries and the biodiversity strategy of Netherlands (table 13). Each analyst started with the national or regional forest strategy. Additionally, and in the case of the region not having one of the above-mentioned documents, the partners could analyse different documents such as laws. This was recommended if they found them more relevant than strategies for guiding practices in their regions. In Germany and Italy for instance, the most relevant strategies guiding decision-making in forest ecosystem services were regional, and were thus chosen for the analysis (Table 13).

Table 14 The 31 policy documents analysed for the database.

	Forest strategies and laws	
Country or Region	**Document name**	**Year**
Europe	EU Forest Strategy	2013
Austria	Austrian Forest Strategy 2020+	2018
Czech Republic	Principles of State Forest Policy	2012
Czech Republic	The National Forestry Programme	2008
Denmark	Danish national forestry programme	2018
Finland	National Forest Strategy	2015
France	Évaluation française des écosystèmes et services écosystémiques - Les écosystèmes forestiers	2018
Germany	Law for the Conservation of the Forest and for the Promotion of Forestry (Federal Forest Act)	2017
Germany - Mecklenburg	State Forest Law	2011

Vorpommern		
Germany - State of Baden- Württemberg	State Forest Law Baden-Württemberg	1996
Germany	Forest Strategy 2020	2011
Germany – Bavaria	State Forest Law Bavaria	2005
Italy	Framework Programme on Forests (Programma Quadro per le Foreste)	2008
Ireland	Forests, products and people. Ireland's forest policy – a renewed vision.	2014
Spain	Boletín Oficial del Estado (BOE) / State Oficcial Newsletter	2015
Slovakia	National Forest Programme of the Slovak Republic	2007
Sweden	Strategy for Sweden's national forest program	2018

Biodiversity strategies		
Country or Region	**Document name**	**Year**
Europe	EU Biodiversity Strategy	2011
Austria	Biodiversitäts-Strategie 2020+	2014
Finland	Biodiversity Strategy	2011
Netherlands	Natuurlijk verder - Rijksnatuurvisie 2014	2014
Germany	National Strategy on Biological Diversity	2007
Germany - State of Baden- Württemberg	State Nature Conservation Strategy	2014
Italy	Biodiversity Strategy	2010
Slovakia	Updated National Biodiversity Conservation Strategy by the year 2020	2013

Bio-economy strategies		
Country or Region	**Document name**	**Year**
Europe	EU Bio-economy Strategy	2012
Austria	Bioökonomie-FTI-Strategie für Österreich (Bio-economy-Research-Technology and Innovation-Strategy for Austria)	2018
Finland	Bio-economy Strategy	2014
Germany	National Policy Strategy Bio-economy	2014
Italy	BIT – Bio-economy in Italy	2017
Sweden	Swedish Research and Innovation Strategy for a Bio-based Economy	2012

The goal was to develop a database allowing a standardized comparative analysis across the Innovation Regions. The database was designed to allow the analysis of innovations and supportive conditions for innovations in the forest sector, while accounting for the diversity of possible information sources and overcoming language barriers. The documents were read and coded, i.e. grading according to the developed operationalized categories of FES, innovations, actors and governance as well as quotes and/or the interpretations of the analyst were entered into a database using an online platform (Webropol). This coding platform was developed in an iterative process allowing several rounds of commenting by the project partners in a face-to-face meeting, over Skype, and via email, to increase inter-coder reliability and streamline with other InnoForESt activities. The iteration aimed at providing a common ground for the final coders and addressing potential uncertainties regarding how innovations, actors and governance could be categorized.

In addition, the partners' earlier expertise and knowledge collected through a brief pre-survey was used as a background for the framing. At later iteration stages, the format of each question supporting the coding was discussed and agreed upon. The final result was a mixture of a few open-ended questions and mainly predefined categories allowing for additions through open questions. The country team members who coded the policy documents were instructed to use the document analysed as their starting point and to only include observations from the documents, refraining from any personal knowledge or opinions.

A comprehensive manual (Annex 2) was developed to aid and standardize the document analysis and coding with Webropol. The aim of the comprehensive manual was to provide explanations to all coding items and the formulation of the questions, clarifying core terms, such as "innovation" or "rights". The manual also contained instructions on the order and ways to code and provided general advice and tips on using the survey tool. We anticipated that not all documents would explicitly address many of the FES, innovations or other factors inquired and thus the manual included examples of operationalisations and implicit mentions of the FES and other factors.

In addition to the manual document, we organized interactive online video training sessions for the people who would code policy documents with Webropol. These were used to train and to calibrate the document analysis together as a group. Altogether three 2.5-hour sessions with similar content were organised. The sessions included the introduction to the structure of the Webropol questionnaire, anticipating technical issues while coding, and a collaborative analysis of FES's wood and bioenergy from the EU forest strategy. The collaborative analysis of the EU Strategy FES helped calibrate answers and resolve uncertainties of interpretations. The results of the collaborative analyses were included in the instruction materials together with the manual.

Analysis of the document data

We analysed the coded material both qualitatively and quantitatively. Generally, most of our analyses used all the 31 documents as material but for some of the analyses, we used only the 10 national forest strategies since they are the most central strategies for FES governance and had been analysed in all the IR and additional countries, this way we were able to secure comparability. Comparison of countries was done through the maps, not seeking to rank the countries in any way. All the quotes we report here are illustrative quotes of the factor we are analysing, rather than pointing to specific countries.

After analysing the purpose of the documents, we started the actual analysis by looking at the concentrations of mentions of FES in the 31 documents we coded. We took each FES as our unit of analysis, with the 31 observations (the documents).

In our analysis of innovations, actors and governance, we analysed again the 10 FES, with 31 observations (N=310). We analysed the mentions of each of the factors with frequencies of categories, and then elaborated by analysing the coded quotes and descriptions of content. In the qualitative analysis of quotes and content, we looked first for typical mentions and then at the more distinct mentions, signalling potential niches.

To visually observe the outcome of the document coding, we produced maps of the countries whose forest strategies we had analysed. These maps can be visually reflected against the hotspots resulting from the biophysical mapping.

Finally, we conducted a Spearman correlation analysis of the biophysical FES hotspots and 280 FES observations from the documents, using the per country hotspot value for each FES, and the 28 observations of each FES. This allowed us to assess the geographical coincidence of biophysical FES supply and institutional FES demand.

3.3 Results from institutional mapping

The results presented in this section are based primarily on our interest on how the forest, biodiversity and bio-economy documents addressed FES and how the different factors (innovation, governance mechanisms and actors) related to the FES.

The document analysis covering 31 European policy documents resulted in an analysis of 310 ecosystem services. The 310 FES analysed allowed observations on how ecosystem services were addressed in various European, national and regional policy. The following section first describes general features of the documents analysed and the ways ecosystem services are presented in them, before a more detailed analysis of innovations, actors and governance in Sections 3.3.2-3.3.5. The main parts of the following analysis especially concentrate on the forest strategies and other forest policy documents as they are the central documents guiding national or regional forest policy. The bio-economy and biodiversity strategies illustrate the possible synergies and/or topical overlaps the documents have for the management of ecosystem services in forests and the emergence of innovations in the regions.

Purpose of the policy documents

Sustainable management of resources was a shared theme in the purpose of all the policy documents analysed. The stated purpose of the *17 forest policy documents* was generally to ensure sustainable forest management, promote forestry and ensure availability of biomass and a balance in the multiple uses and interests for forests (see image 1). Diversifying forest use for competitiveness and environmental friendliness to e.g. support bio-economy growth (Sweden and EU strategies) was also mentioned, displaying a link between forests and bio-economy. Some document visions highlighted the need for collaboration of regional actors and other actors in forest policy implementation, for planning forest use or balancing public interests with landowners. In addition to sustainable forest management, direct mentions of support for biodiversity conservation appeared too.

The *8 biodiversity strategies* were frequently framed as being developed to respond to the UN Convention on Biological Diversity (CBD) and accordingly halting biodiversity loss. Sustainable use of biodiversity and reaching a balance between socio-economic interests and conservation were mentioned. The *6 bio-economy strategies* underlined the reduction of fossil fuel use and finding innovative and sustainable uses for biogenic resources in order to create competitiveness in the bio-economy sector. Innovation was mentioned directly in three bio-economy strategies.

Figure 24. Word cloud of the coded "Stated purpose of the document" of the 17 analysed forest policies.

Forest ecosystem services

The concept "ecosystem services"

The concept of ecosystem services was mentioned either directly or indirectly via nature's or forest's benefits to humans in all the analysed documents, except one. Nine of the 17 forest documents mentioned ecosystem services directly. This was often when referring to the EU Forest Strategy. The phrase also appeared in the contexts of sustainable forest management for protecting ecosystem services and the multi-functionality of the forests, wood and non-wood benefits of forests for society and the economy, monetary values of ecosystem services and the importance of forests for carbon sequestration and climate control.

The biodiversity strategies mentioned ecosystem services almost always directly: seven out of eight biodiversity strategies had direct references to the concept. The term was often coupled with the term "biodiversity", occasionally with terms such as natural capital and green infrastructure. ES were described as something that need to be conserved and protected and their importance for human survival and life underpinned. ES were something to be taken into consideration in planning and management and awareness regarding them should be raised. The way the term was discussed can be interpreted as perceiving ecosystem services and expressing their value as something that aids achieving the objective of halting biodiversity degradation.

The bio-economy strategies had the most economically or socio-economically oriented mentions of ES. The concept appeared directly in four out of the six analysed bio-economy strategies. Generally, it was mentioned in the context of wellbeing, recreation or sustainable uses of biomasses that are vital for bio-economy and the need to valorise ecosystem services. The role of healthy forests for climate regulation, adaptation and sustainable and continuous wood production were mentioned a few times in the German documents. Protection of biodiversity and balanced exploitation of functions of soil and forests which deliver societal public goods, also non-market ecological benefits were also coded as indirect mentions of ES. ES were seen as a necessity for fulfilling the purpose of the bio-economy strategies.

Table 15. Distribution of forest ecosystem service mentions in the 31 analysed policy documents, (percent of policy document type).

% **Forest policies**	Wood	Bioenergy	Non-wood products	Game	BD con.	Erosion, water protect.	Climate reg.	Recreation	Cultural heritage	Resilience	TOTAL
A central objective	**64,7**	**47,1**	5,9	17,6	**41,2**	**41,2**	**35,3**	**41,2**	0	11,8	31
Stated as an objective	**29,4**	**17,6**	11,8	23,5	**41,2**	**29,4**	**35,3**	**41,2**	**47,1**	**53**	33
Mentioned directly	5,9	5,9	47,1	29,4	5,9	11,8	11,8	11,8	17,6	11,8	16
Mentioned indirectly	0	0	0	11,8	11,8	5,9	5,9	5,9	11,8	0	5
No mention	0	**29,4**	**35,3**	**18**	0	11,8	11,8	0	**23,5**	**23,5**	15
Total (N=17)	100	100	100	100	100	100	100	100	100	100	100 (n170)
Biodiversity strategies											
A central objective	0	0	0	0	**75,0**	0	12,5	12,5	0	0	**10**
Stated as an objective	12,5	25,0	0	25,0	12,5	12,5	37,5	12,5	0	0	13,8
Mentioned directly	37,5	12,5	0	12,5	12,5	12,5	25,0	0	25,0	25,0	16,2
Mentioned indirectly	37,5	0	12,5	0	0	25,0	0	0	0	25,0	8,8
No mention	25,0	**62,5**	**87,5**	**62,5**	0	50,0	25,0	**75,0**	**75,0**	50,0	**51,4**
Total (N=8)	100	100	100	100	100	100	100	100	100	100	100 (n80)
Bio-economy strategies											
A central objective	**50,0**	**66,6**	16,7	0	16,7	0	16,7	0	16,7	16,7	20,0
Stated as an objective	33,3	16,7	0	0	16,7	33,3	33,3	16,7	0	16,7	16,7
Mentioned directly	16,7	16,7	**50,0**	16,7	**50,0**	16,7	33,3	33,3	16,7	16,7	26,7
Mentioned indirectly	0	0	16,7	0	16,7	33,3	16,7	0	16,7	16,7	11,7
No mention	0	0	16,7	**83,3**	0	16,7	0	**50,0**	**50,0**	33,3	**25,0**
Total (N=6)	100	100	100	100	100	100	100	100	100	100	100 (n60)

All of the 10 FES analysed were mentioned in over 50% of the documents (Table 10). Forest, biodiversity and bio-economy strategies differed in how they addressed FES. Out of the 10 analysed FES, wood, bioenergy and biodiversity were most frequently identified as central goals in the 31 documents (Figure 1). Biodiversity conservation was the only FES that was in some form mentioned in all the documents. As mentioned earlier, the purpose of many of the analysed strategies was to conserve or sustainably manage natural resources, e.g. biodiversity, and in some cases even more specifically forest biodiversity:

"Maintenance, enhancement and restoration of forest biodiversity across all Austrian forest areas"

(Austrian forest strategy 2020+, strategic goal)

Many strategies did not address non-wood forest products (game or edible plants) or cultural heritage at all. Where cultural heritage was mentioned, it was generally connected to recreation or cultural historic values of landscapes or traditional lifestyles.

"The forest has always been of special importance to the people of Germany. It shaped German culture and found its way into myths, legends, poems and songs."

(Forest Strategy 2020, Germany)

Edible plants and other non-wood products were also sometimes connected to cultural heritage in the forms of berry or mushroom picking, traditional uses of wild plants etc. The economic value of non-wood products was mentioned in the Finnish Forest Strategy and the EU bio-economy strategy.

"Beyond the domain of wood-based products, non-wood (or wild) forest products and forest-related ecosystem services deserve to be mentioned. The former include a number of products – such as mushrooms, truffles, herbs, cork etc.- which often have a strong link to traditional knowledge, local economies and forest management practices"

(BIT – bio-economy in Italy, Italy)

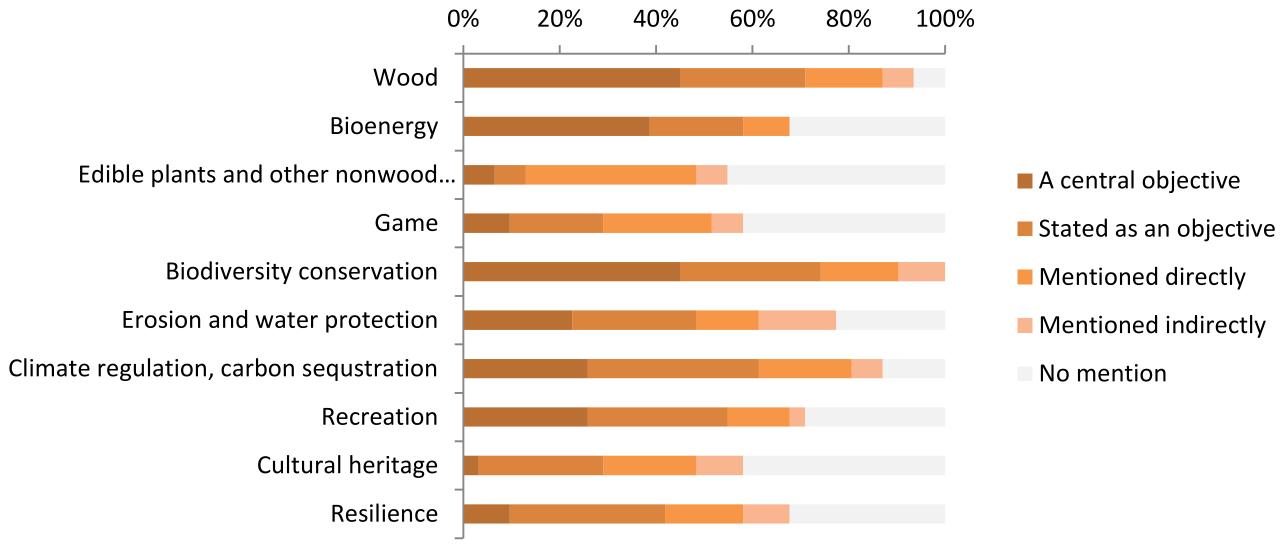

Figure 25. Forest ecosystem service types and their weight in all 31 documents analysed

FES in forest strategies and laws

As was to be expected, the 17 forest strategies and laws had relatively the most numerous and clearest mentions of different forest ecosystem services (Table 10). Wood or timber was mentioned in its traditional uses and also as potential for new uses of wood in e.g. construction, chemicals, and fibres, for example:

"From a life cycle perspective, there are climate benefits of using more wood in construction, as industrial construction wood means shorter construction time, lower emissions and less disturbance in the sustainable society."

(FES Wood, Strategy for Sweden's national forest program)

Sustainable use of forests and wood was mentioned several times. Woody biomass was often mentioned as an important renewable energy source, and the strategies identified the potential of forests to meet the growing demand for energy. However, bioenergy was not mentioned in 5 of the 17 documents.

Direct mentions of the recreational use and nature tourism in forests were apparent in many documents. To support sustainable use of forests, there were suggestions to develop conservation areas and improve the development and maintenance of recreation infrastructure.

Resilience and climate regulation especially to mitigate climate change and maintain forests as important carbon sinks were mentioned in most of the forest strategies. Forests were framed as both affected by climate change but they were also considered to offer solutions:

"Forests are vulnerable to climate change. It is therefore important to maintain and enhance their resilience and adaptive capacity, including through fire prevention and other adaptive solutions (e.g. appropriate species, plant varieties, etc.)."

(FES resilience, EU Forest Strategy)

Game and non-wood products were often either not mentioned at all or mentioned vaguely in a list or indirectly as a by-products or amenities. Berry picking and hunting were small scale local activities often connected to recreation. The documents from Sweden and Finland had slightly more explicit mentions of these FES, but still not clear objectives or targets related to them.

"The total value of traditional natural products – berries, mushrooms and game – also amounts to hundreds of millions of euros annually. They are an important by-product of the forests, both economically and socially."

(National Forest Strategy 2025, Finland)

FES in biodiversity strategies

In the eight biodiversity or nature conservation strategies, biodiversity conservation was the most central FES, since these strategies were motivated by and targeted halting biodiversity loss and fostering biodiversity.

Climate regulation and carbon sequestration was also stated as a central objective or objective in four biodiversity strategies and was generally related to the idea that protecting biodiversity and forests would lead to improved carbon sequestration and help combat climate change.

"Forests represent major reservoirs of carbon and play a vital role in global climate regulation by contributing to the health of our country and reducing greenhouse gas emissions"

(FES climate regulation, Biodiversity Strategy, Italy)

"Agriculture and forestry are [therefore] of particular importance and responsibility for biodiversity conservation."

(FES biodiversity conservation, National Strategy on Biological Diversity, Germany)

Interestingly the biodiversity strategies did not mention any of the provisioning services as central objectives; they frequently did not mention them at all. Similarly, the recreation and cultural heritage received little attention in the strategies even though the stated purpose of the strategies often included the idea of nature as central for human wellbeing. Approximately 50% of the FES were not mentioned at all in the biodiversity strategies (Table 10).

FES in bio-economy strategies

In the six bio-economy strategies, wood and bioenergy were the FES framed as main objectives. Similar to the forest strategies, wood was the most explicitly measured FES and the targets for its use as well as economic impacts in society in the form of jobs and profits were expressed clearly. Also the innovation potential for wood and bioenergy sources was brought up occasionally.

"The forest-based industries are a very important EU economic sector (woodworking industries, pulp and paper, printing industries), with a production value of € 365 billion, and an added value of around € 120 billion created by more than 3 million jobs."

(FES wood, EU Bio-economy Strategy)

"Solid biomass fuels (among these wood) represent the main renewable source of energy on a national scale"

(FES bioenergy, BIT – Bio-economy in Italy)

25% of the FES were not mentioned at all in the bio-economy strategies (Table 10). Not so surprisingly, the cultural ecosystem services together with game were the least frequently mentioned FES in the bio-economy strategies.

Forest ecosystem services and innovations

When analysing the different innovation types from all the 31 documents jointly, we found that a third (66%) of the bio-economy strategies had innovations related to the mentioned FES, whereas the biodiversity and forest documents had innovations related to the just over half of the mentioned FES (51% in forest documents and 55% in biodiversity strategies). Strategies contained twice as many mentions of innovations in comparison with the law documents (60% of strategies vs. 31% of laws).

Most of the mentioned innovations were related to wood, while bioenergy and biodiversity conservation also had ~40 mentions of innovations (Table 11; Figure 22). The cultural ES had the least innovations related to them (37%), while approximately two thirds of the provisioning and regulating services had innovation mentions. Most innovations were in the initial phases, promoting, and only a small number of innovations were in the upscaling stage.

Table 16. Innovations related to forest ecosystem services mentioned in the documents.

Innovation type	Wood	Bioenergy	Non-wood products	Game	Biodiversity conservation	Erosion & water protect.	Climate regulation	Recreation	Cultural heritage	Resilience	Total
Process	16	14	1	1	10	6	9	5	0	9	71
Social process	17	7	1	2	10	4	4	5	2	1	53
Product	15	10	4	3	1	1	7	2	2	1	46
Service	12	6	2	0	8	0	4	6	1	4	43
Market	10	9	2	0	9	4	4	3	0	1	42
Total	70	46	10	6	38	15	28	21	5	16	255
No mention	75	59	75	84	117	105	107	89	85	89	885
TOTAL	145	105	85	90	155	120	135	110	90	105	1140

The more weight a FES was given in a policy document the more innovations were mentioned (Figure 23). The central objective FESs had clearly the highest proportion of all innovation stages (figure 24). The innovation mentions that were classified as upscaling innovations generally had clear targets and actions stated in the policy document, e.g.: *Danish energy and CO2 taxes imposed on fossil fuels in heat production (already implemented), electricity charges the competitive relationship between heat pumps and biomass in the decentralized combined heat and power plants in favour of the use of biomass from forests, among others.*

(Market innovation FES bio-energy, Danish national forestry programme)

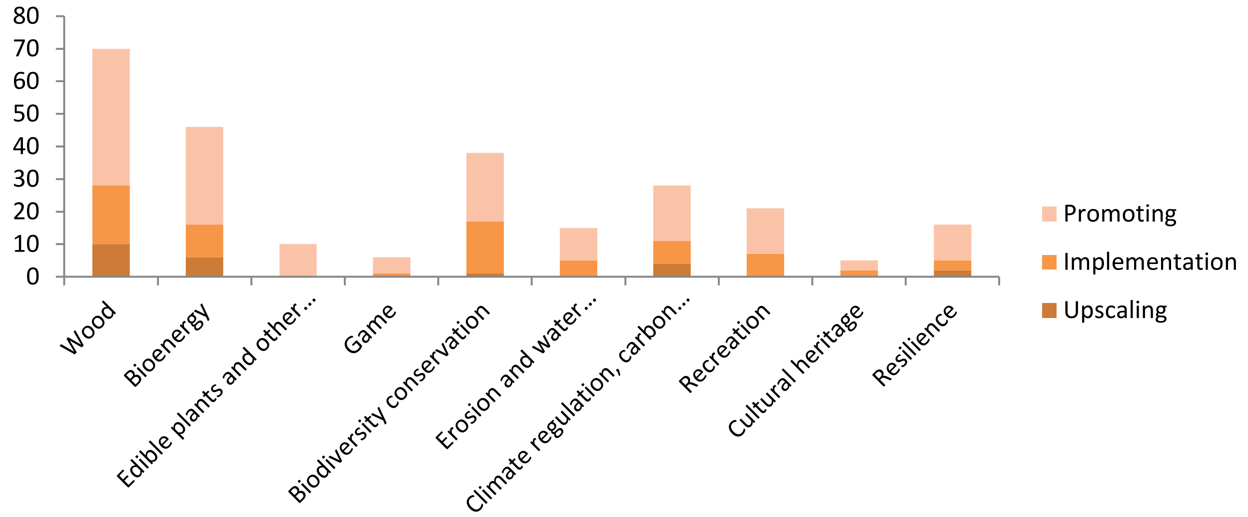

Figure 26. Number of innovation mentions classified into stages related to mentioned FES (n=255).

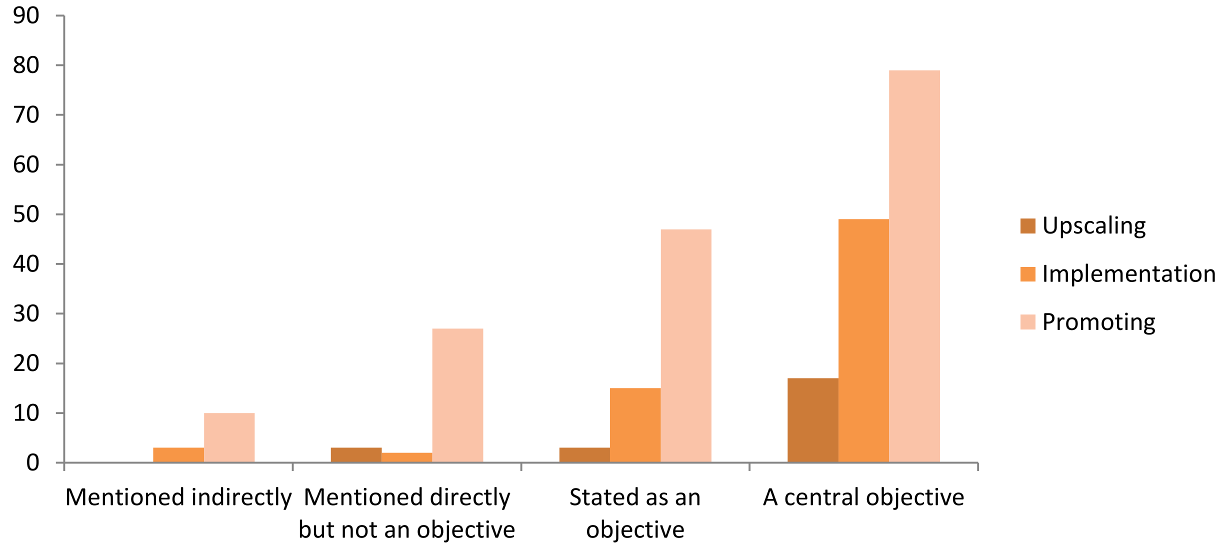

Figure 27. Distribution of the innovation stage on the weight placed on the FES in the documents.

We analysed five different innovation types in the 31 policy documents: product, process and technology, social process and networking, service and market rearrangement innovation.

Process and technology innovations were the most common innovation type out of the 255 mentions of innovations (Table 11). They were identified across different ecosystem services, most apparently associated with wood and bioenergy. Also biodiversity conservation, climate regulation and resilience were associated with process and technology innovations. The identified process innovations related to new management or planning practices including networks or planning tools and finding new technologies for conservation of natural resources and anticipation of risks. Some of the process innovations related to also natural process or types of nature-based solutions within the forest in contrast to human induced innovation processes, e.g. afforestation as climate action.

To optimise technological processes to save or reuse water

(FES Erosion and water protection, bio-economy strategy, Austria)

Social innovations(processes and networking) were predominantly related to wood and additionally in biodiversity conservation and bioenergy. These innovations were described as new forms of cooperation and partnerships between different actors and improving communication and engagement via public participation in e.g. planning of forests and ecosystem services. Platforms and networks to enhance cooperation were the concrete measures of some of these partnerships. Additionally, new cooperation models for training and education and other types of educational projects were also mentioned.

"Regional cooperation, interaction between industrial sectors and new services that support the exploitation of surplus materials will enable efficient use of materials close to where they are produced."

(FES wood, bio-economy strategy, Finland)

From the open responses to the innovation questions it became apparent that the difference between an innovation and a governance mechanism was not always clear and left room for interpretation in the documents. A novel governance mechanism could also be mentioned as an innovation. For this reason we examined the relations between social process innovations and collaborative and distributed governance mechanisms. Collaborative governance was mentioned in relation to 78 FES (of 228) and in 37 of the occurrences social process innovations were also mentioned. In some cases the response from social innovation was duplicated in the collaborative governance section.

Product innovations were also almost exclusively related to the provisioning FES, mainly wood and bioenergy. This is understandable as product innovations tend to be something tangible. However, curiously there were 7 mentions of this innovation type related to climate regulation. This is explained by an interpretation of product innovations of other FES, such as wood or biofuels, to have an expressed climate impact and producing products with lower carbon emissions e.g. more building material from wood.

”--growing demand for raw material for existing and new products (e.g. green chemicals or textile fibre)”

(FES Wood, EU Forest Strategy)

Service innovations, (together with market innovations) were less frequently mentioned innovation types, aligning with social process and networking innovations. Recreation was mentioned in this type most often and it generally referred to improving recreation infrastructure and the emergence of new business opportunities or forms of (eco)tourism and other recreational activities. The service innovations identified included also the engagement of diverse actors especially in land-use planning processes. Consultancy services and capacity building for interested or improving research and the availability of information was also seen as a service innovation.

“a database to collect and share data on biomass and bio-waste actual and potential availability”

(FES bioenergy, BIT – bio-economy in Italy)

Opportunities of forestry for development of small-scale business, tourism and services based on social functions of forests (recreational, health and aesthetical) are determined by very diverse natural conditions in forest communities.

(FES recreation, National Forest programme of the Slovak republic)

Market rearrangements were mostly related to wood, bioenergy or biodiversity conservation. These innovations included different forms of payments for ecosystem services (PES) and the removal of harmful subsidies in the context of biodiversity conservation. The payments could come from either business or tourism and be aimed at forest owners. Changes in public procurement standards, paying more attention to sustainability and regulation in the global wood markets, diversifying markets and integrating ecosystem services and biodiversity elements into business models were also brought up as shifts in the traditional ways of markets.

"Bio-based products and bioenergy can be «bio-based versions» of traditional products or novel products with entirely new and innovative functionalities and potential for new and existing markets. To exploit this, the EU is actively driving further development of clear and unambiguous product standards and sustainability criteria at European and international level. These are central for the functioning of the Single Market and the further development of certification and labels that can promote consumer uptake and green public procurement."

(EU Bio-economy Strategy)

Forest ecosystem services and actors

To understand the role division in FES provision and benefiting, we analysed the direct and indirect mentions of actors in the documents, through the coding of responsibility for FES and rights to FES. This analysis includes quotes and interpretation of the – rather few –mentions that were associated with rights to FES.
For *responsibilities* the strategies mentioned actors related to the stewardship of public forests, like Metsähallitus in Finland or Collite in Ireland, international organisations like IPBES and the CBD or other specific platforms, committees, organisations or projects related to different forms of collaboration and research.

Responsibilities

Public administration actors of different levels were the most frequently mentioned category of actors with identified responsibilities (Figure 25). Especially national and regional administration responsibilities were noticeable which was to be expected as they are often central for designing and implementing the policy documents. The EU strategies expectedly had more mentions of the EU as a centrally responsible entity. European level administration was the least mentioned actor in the documents (81,1% not mentioned), followed by educational bodies (79,8%) and recreational users (77,6%).

National administration, forest industry, landowners and research were the only four actors that had slightly more mentions than non-mentions, being mentioned between 50,9% to 72,4% of the cases analysed (n = 228). *Forest industry* was most mentioned in connection with FESs wood (79% mentioned), bioenergy (71%), biodiversity (65%) and resilience (57%), which were also the main responsibilities of *research* in addition with climate regulation (63%). For *landowners* responsibilities related also mainly to wood (72%) and biodiversity conservation (68%) but also strongly to game (67%) and surprisingly most highly to recreation (73%).

However, in connection with recreation landowners did not generally have the most *central* responsibilities, but clear responsibilities nonetheless.

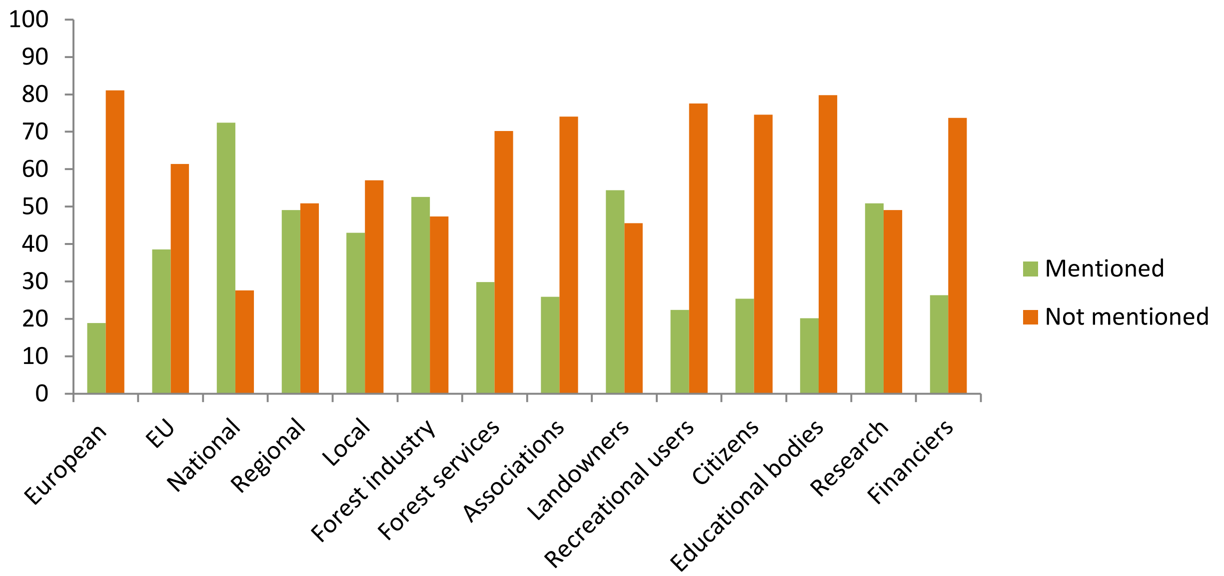

Figure 28. Proportion of mentions of actors and responsibilities relative to the 310 analysed FES.

As the public administration had clearly the most responsibilities, we looked in more detail to which FES they were connected. The public administration actors' responsibilities were mainly connected to the FES that were most often mentioned in the documents; wood, bioenergy, biodiversity conservation and climate regulation (table 4). For these FES they tended to have clear or central responsibilities. For the FES that were less central in the strategies, e.g. non-wood and game (see table 2) there were also fewer responsibilities assigned for public administration.

Table 17. FES and public administration actors (% of all mentions in each FES).

%	Wood	Bioenergy	Non-wood prod.	Game	BD conservation	Erosion water protection	Climate regulation	Recreation	Cultural heritage	Resilience	TOTAL
Central responsibilities	17	15	6	13	20	12	16	8	6	10	13
Clear mention and responsibilities	23	9	5	9	9	7	10	6	4	10	10
Clear mention, no clear responsibilities	17	19	0	2	11	8	10	7	7	4	9
Indirect mention	9	16	13	8	8	8	14	15	17	19	12
No mention	34	41	76	68	52	66	49	63	67	58	56
Total %	100	100	100	100	100	100	100	100	100	100	100

In 45% of the cases in which there was a clear mention that a collaborative governance mechanism would be developed there were central or clear responsibilities assigned to actors. In 44% of the cases that mentioned social innovations there were central or clear responsibilities denoted to actors. Forest industry, landowners, research and public administration actors were the most commonly mentioned actors in relation to both collaborative governance and social innovations. Forest services were mentioned in 54% of the cases in connection with collaborative governance.

Rights

As we recorded open text examples of mentions only for rights and not responsibilities, the open text answers often showed that some rights could be interpreted as responsibilities as well.

For rights the mentions of *public administration* once again stood out with the highest proportion of mentions of rights to 228 FES mentioned (figure 24). Examples of public administration rights (and likely also responsibilities), included the right to plan forest management, draft laws, policies, guidelines and regulation and carry out and delegate monitoring, data collection and coordination activities related to the majority of the FES mentioned earlier. The rights were often associated with the same ecosystem services as the above-mentioned responsibilities. Also ensuring sustainability, adaptation to climate change, managing risks and conserving biodiversity for future generations were also mentioned as the rights of administration. Directing funds or organising funding for forest related activities such as biodiversity conservation were mentioned. Coordination with international actors and commitments was also the right of public administration. Administrative actors were the ones with the right to prohibit certain actions of e.g. land owners or recreational uses of forests. Ministries and state or regional agencies were the actors specified under this category.

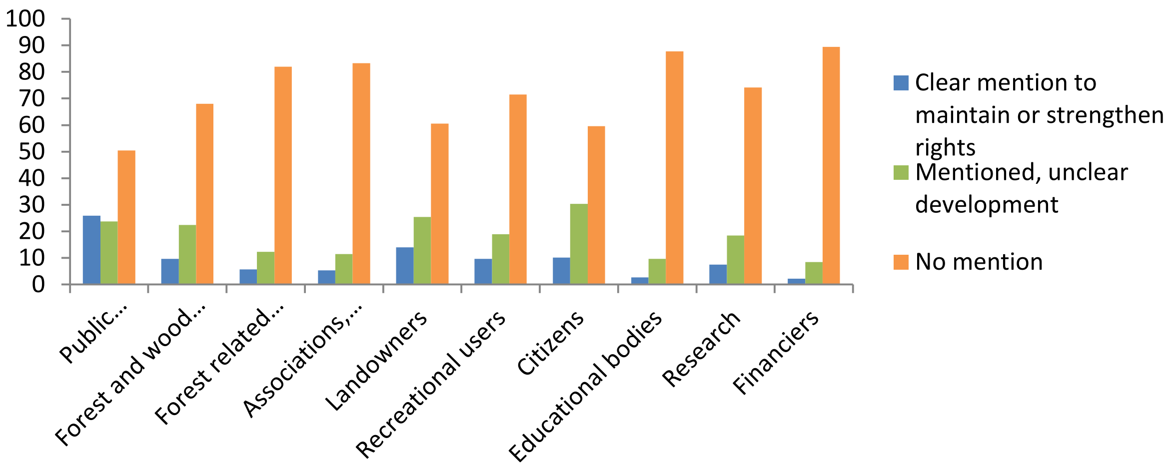

Figure 29. Mentions of actors' rights relative to the 228 mentioned FES.

Citizens were the second most frequently mentioned actor type as holding rights (fig. 25). These included the right to benefit from nature in the forms of recreation, right to a clean environment, right to use nature sustainably. According to one strategy, access to nature should be socially balanced. These ideas reflect the environment as a public good and essential for human wellbeing also for future generations, which was also explicitly mentioned in some of the documents. One mention indirectly specified art and culture around nature as a source of wellbeing. Citizens and social uses of forests were seen as creating acceptability for the non-use or not implementing forestry in all forests.

"--the nature and nature experiences are an important source of well-being"

(Bio-economy Strategy, Finland)

In terms of landowners' rights, the right to biodiversity conservation and receiving monetary compensations for conservation, and recreation were identified. Additionally, property rights and a right to receive information regarding issues such as sustainable forest management and the status of their forests and protection and information on risks such as flooding were mentioned in the quotes. In one document, landowners were perceived as having a function in awareness-raising on forests. Hunting was also a landowner right:

Hunting in the cultural landscape is necessary to avoid substantial economic and ecological damages.

(National Strategy on Biological Diversity, Germany)

Limiting access to their lands was a landowner right and could be justified e.g. by game management needs. Participation in negotiating issues related to access and changing the uses of their lands (e.g. from agricultural lands to recreational ones) was also identifiable as their right, as well as stability and longer-term visions of land-use planning.

We expected landowner rights to be more central in the analysed documents from the countries that have a high percentage of privately owned land (table 13) but the document analysis did not confirm this assumption.

Table 18. Actors' rights and FES type relative to the analysed 228 FES (% of FES mentioned).

%	Provisioning	Regulating	Cultural
Public Administration	58	49	35
Forest industry	48	29	5
Forest services	31	7	20
Associations	22	12	18
Landowners	47	33	40
Recreation users	29	14	65
Citizens	38	34	63
Educational bodies	18	7	15
Research	36	21	15
Financiers	20	6	3

The rights of landowners and the forest using business and industry were generally connected to provisioning services, where clear resource or land rights might be more apparent. In contrast the rights of recreational users and citizens were connected to the cultural services that would not necessarily require ownership or tangible possessions. Rights were generally less frequently mentioned relative to regulating services with the exception of public administration often being clearly mentioned in connection with biodiversity conservation, climate regulation and resilience, and citizens and landowners being indirectly mentioned in them, especially with biodiversity conservation.

Table 19. Clear mentions of actors' rights to FES relative to the analysed 228 FES (% of FES mentioned).

	Wood	Bioenergy	Edible plants	Game	Biodiversity con.	Erosion and water prot.	Climate regulation	Recreation	Cultural heritage	Resilience	TOTAL
Public Admin.	48	29	12	39	26	17	19	27	11	24	26
Forest industry	41	14	6	0	10	0	4	0	0	10	10
Forest services	24	10	0	6	6	0	0	5	0	0	6
Associations	7	0	0	28	7	0	0	5	6	5	5
Landowners	38	0	12	28	16	0	7	14	6	14	14
Recreation users	14	0	12	11	3	0	0	50	11	0	10
Citizens	14	5	6	6	13	8	0	27	11	10	10
Educational bodies	14	0	0	0	6	0	0	0	0	0	3
Research	28	5	0	0	10	0	4	0	0	19	7
Financiers	7	5	0	0	3	0	0	0	0	5	2

Forest and wood using business and industry rights were identified more unclearly except for the right to wood which was mentioned clearly. They were identified as having the right to benefit from research and have a sustainable operating environment and materials, or lobby for their needs. Risk management and avoiding risks such as pests was also seen as the right of industry. Development of new and more ecologically sound technologies and operating and management procedures were also mentioned. For bioenergy specifically, one mention was the industry's right to benefit from the side streams of wood production. Industry was perceived as a stakeholder with the right to participate in different fora where its operations were governed.

"Agriculture, forestry, fisheries and aquaculture require several essential and limited resources to produce biomass. These include land, sea space, fertile and functioning soils, water and healthy ecosystems, but also resources such as minerals and energy for the production of fertilisers."

(EU Bio-economy strategy)

Associations, NGOs and civil society actors were generally mentioned in a vague manner, their clearest right being connected to the FES Game. This related to the fact that there were hunting organisation or associations mentioned directly in this category. Mainly the rights of association related to some form of participation in education and awareness-raising on environmental issues or involvement in nature conservation and sustainable recreation activities guidelines formulation. Participation as a stakeholder in the EU was mentioned. The Finnish Strategy on biodiversity explicitly mentioned the participation rights of the Sami people and infrastructure services and non-wood products social and economic values as a right for civil society.

Half of the clear mentions of right for *recreational users* were related to the FES recreation (Table 19). Other FES for which this actor held rights were wood, biodiversity conservation and cultural heritage. The same trend was visible for *citizens***,** whose clear rights were related to mainly the same FESs. In these contexts the ideas of everyman's rights (the public's right to freely access public and private lands for recreation) , rights to a clean and healthy environment of current and future generations were mentioned. One right was access to information regarding biodiversity. Benefitting from new sustainable energy sources was also a right of citizens.

"It is also fundamentally important to provide the public and the forest industry with the earliest indication of the areas where potentially sensitive issues may arise in relation to, for example, landscape, water quality, archaeology and biodiversity."

(Citizen right, FES Erosion and water protection, Forests, products and people. Ireland's forest policy – a renewed vision)

Jobs, and wellbeing at these jobs, in fields related to the forest environment and new forms of income and employment were also brought up in relation to e.g. the bioenergy sector.

"The greatest competitive advantage for the sector is motivated personnel, and occupational welfare and up-to-date personnel skills must be ensured."

(Citizen right, FES wood, National Forest Strategy 2025 Finland)

Research was also mentioned rather vaguely and infrequently. Its rights were clearly mentioned more than once only for three FES, the most prominent being wood. The right-mentions were also mainly responsibilities, e.g. rights to monitoring, assessing climate change impacts, spatial planning. Some mentions were connected to the right to receive funding for research activities. *Educational bodies* were among the least mentioned actors with rights, wood and biodiversity conservation being the FES they related to.

Financiers were the actor with least mentions of rights. The few mentions were in connection to wood, bioenergy, conservation and resilience.

Governance and forest ecosystem services

The original version of the database contained 6 categories of governance mechanisms (market-based, incentives, regulation, collaborative, information and disruption) related to the ecosystem services (chapter 3.1.3), but since very few responses were coded under "disruption" we have excluded the category from this analysis.

Governing with information or regulation were clearly the most popular mechanisms found in the policy documents with 42,1% and 43,4% of mentions respectively, with market governance having the fewest mentions (table 20).

Table 20. The distribution of the mentions of governance mechanisms in the 31 policy documents.

	Markets	Incentives	Regulation	Collaborative	Information
Clear mention of development	7	15	12	13	18
Mentioned	16	17	31	21	24
No mention	77	68	57	66	58
Total	100	100	100	100	100

Development of *regulation* was frequently identified in the documents, in particular for wood, bioenergy and biodiversity conservation (Table 20). Some documents mentioned different EU level directives and guidelines, such as the Birds and Habitats directives, EU energy directives, Water Framework directive, forestry regulation and the Natura 2000 network in relation to governing certain FES.

"Environmental objectives have been established for all groundwater and surface water bodies in Ireland in the River Basin Management Plans which were adopted and published by Local Authorities in 2010 in compliance with the EU Water Framework Directive (WFD)."
(FES Erosion and water protection, regulation, Ireland's forest policy)

Nature protection laws have provisions for the protection of nature, conservation, building lines and access rules, which are important for the forests. Finally, hunting and game administration have significance for the management of forest fauna.
(FES Game, regulation, Danish national forest programme)

Regulation also applied to most of the other FES. However, the cultural FES were not as strongly governed with regulation, but rather with information (Table 21). These types of mechanisms included different types of guidelines, statistics, awareness-raising and advice services from different types of agencies for different audiences interested in or with knowledge needs related to cultural services. Information governance was fairly commonly mentioned across the FES, though least with edible plants and other non-wood products.

The Agency for Culture and Palaces can give information on the position and extent of all antiquity memories
(FES Cultural heritage, information, Danish national forest programme)

Collaborative governance was strongly connected to wood, but also bioenergy, recreation and biodiversity conservation. These mentions focused on supporting the emergence of different collaborative platforms for dialogue, increasing cooperation with neighbouring countries and other relevant stakeholders such as local communities, practitioners, indigenous groups etc. Networking and setting up new boards or cooperatives were also frequently mentioned in the open text responses.

To improve coherence and cross-sectoral cooperation between forest management and other related sectors with the aim to harmonise economic, ecological and socio-cultural objectives.
(FES Biodiversity conservation, collaboration, Forest programme of the Slovak republic)

Table 21. Governance mechanisms in relation to the 10 FES (% of mentions).

%	Wood	Bioenergy	Edible plants	Game	Biodiversity cons.	Erosion and water prot.	Climate regulation	Recreation	Cultural heritage	Resilience	Total
Markets	52	33	12	11	26	21	7	27	22	5	23
Incentives	62	62	6	17	42	17	37	18	11	19	32
Regulation	59	62	35	50	61	38	41	36	17	19	43
Collaboration	69	43	24	28	39	21	22	41	17	24	34
Information	59	33	12	33	55	29	56	41	39	43	42

Incentives by government were frequently mentioned as being developed for especially wood, bioenergy, biodiversity conservation and climate regulation (Table 21). Incentives were suggested for all other FES in some documents, at least indirectly, with edible plants receiving the least mentions. Programmes or economic incentives for development of certain sectors e.g. tourism, carbon neutral energy, certain forest management practices or rural development were some of the concrete mentions for incentives. Subsidies and taxation were mentioned in this category a few times. Fostering government funded research or research programs related to the FES in question also came up.

"…incentives to production of energy from biomass-based plants through the concession of green certificates…"

(FES bioenergy, incentives, Italian framework programme for forestry)

Market mechanisms were directly and indirectly identified to be developed mainly for wood and indirectly or with unclear mention for bioenergy and biodiversity conservation and for some other FES.

"Special recreational offers, especially professionally organized and conducted events, should in principle be rewarded financially by the user."

(FES Recreation, market governance, Forest strategy 2020 Germany)

4. Interaction between biophysical and institutional analysis

In this chapter we present results from two diverse approaches to interpret what types of interactions exist between the biophysical and institutional data. First we give a brief overview of our online maps that illustrate the two datasets visually (4.1). Here we also include reflections from the IRs on how the maps depict the country contexts of the innovations (4.2). Second, we present a statistical correlation analysis between the biophysical FES hotspots and the FES, innovations and governance mechanisms from the institutional analysis (4.3).

4.1 Maps and visual analysis of the data sets

To assess the coincidence of FES supply and institutional demand visually, we combined the biophysical supply of FES and institutional demand data. We did this by visual analysis of maps and correlation analyses.

We started by developing maps that overlaid the hotspot percentages of the countries for which we had analysed the coded FES weight, innovations, actors' rights, actors' responsibilities and governance in the ten national forest strategies analysed, to maintain comparability. This allowed us to visually observe some of the contextual factors that might be relevant for the governance of the FES and also the emergence of innovations. See Figure 26 for an example. It displays biophysical FES hotspot Erosion control (black-green) and institutional demand for FES Erosion and water protection, i.e., the emphasis placed on this FES in forest strategies.

The maps are available [online][1].

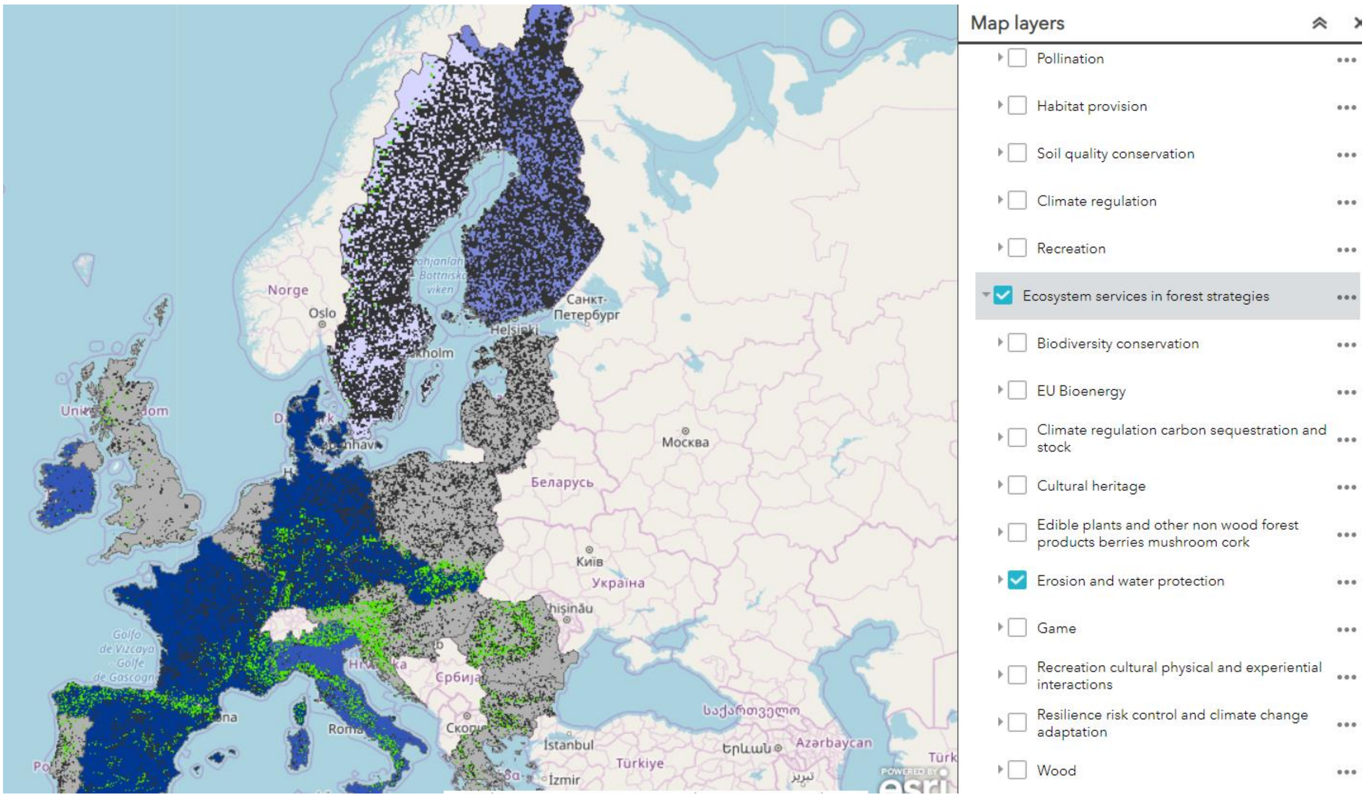

Figure 30. An example of an online map displaying the biophysical FES hotspot Erosion control (black-green) and institutional demand for FES Erosion and water protection, i.e., the emphasis placed on this FES in forest strategies (shades of blue). Grey denotes no.

[1] http://syke.maps.arcgis.com/apps/webappviewer/index.html?id=e27ae600fad1451fa3ed4109ae309856

While the biophysical FES maps have generally 1km accuracy, the institutional maps summarize policy at a national level, country by country. For this reason, the institutional maps are more general. Several maps displaying ecosystem services in Europe have been produced recently (Burkhard et al., 2012; Maes et al., 2013; de Rigo et al., 2013; Avitabile and Camia, 2018). The aim of our map platform is not to compete with these maps but rather to give a general view of the coincidence of the biophysical FES supply and institutional demand. Nor are our maps comprehensive in the sense of providing detailed data regarding contexts where the project innovations operate, as they are too general for this kind of operational local level use.

4.3 Interpreting the maps

To evaluate the robustness of the policy analysis and to pre-test the potential uses of the maps and further develop them, we asked the Innovation Regions to reflect on how the information displayed in the maps might resonate with their innovations and help explore underlying elements of the IRs. How different users, e.g. innovation developers, policymakers, landowners, etc., interpret the maps may vary according to their interests in forests and forest management. The different IRs may also have different needs and interpretations regarding the maps. Here we present the perceptions that were shared among most IRs and examples from four IRs (Sweden, Italy, Germany and Finland) on how the maps support or conflict with their understanding of the current situation of forest management and policy in their country. In the future (D2.3) we continue to improve the maps and their usability to make them more integrated in the overall needs of the project.

The first constrain in the use of the maps was not being able to view several national-level layers simultaneously. The map only allows viewing one layer at a time since the colouring covers the whole country but more layers can be selected and the information regarding them explored with a small info-box that comes on top of the country showing all the information from the selected layers.

Discussions with the IRs and other WPs also made it evident that the map is not a stand-alone version, but requires either this deliverable or some other type of guideline to interpret what is behind the different categories mapped, e.g. what could be an example of a service innovation. The basic information about the source of the coding, i.e. the policy documents, is available on the info page of the maps and in the metadata, but not visible upon looking at the different layers. Thus we recommend that the map only be used in connection with this deliverable since other solutions to the issue are beyond the scope of this project.

It was also apparent that the maps would not function as a tool for local practitioners wishing to learn about different uses for their forests. Some of the IRs expressed that it would have been meaningful to allow for example landowners to evaluate novel and possibly sustainable uses for their forests by exploring the maps, but obviously national level information limits this type of usability. Eventually the maps may include pins about different FES related innovation across Europe. This information has been produced by the SINCERE project (https://sincereforests.eu/). Additionally more detailed info-boxes regarding the InnoForESt IRs will be placed on the map eventually.

The Innovation Region science partners also analysed how the maps reflected the national context in which the innovation is being developed.

Sweden

In Sweden, the focus on particular climate related FES in the documents that were analysed for the institutional mapping reflects the results of the biophysical mapping. Although Sweden's forest biomass per ha is lower compared to other mid-latitude European forest ecosystems, the extent of forests in Sweden and its effective production systems compensates for this. The broad focus on a range of FES in Swedish Forest Strategy, including biodiversity habitat and recreational services, is in line with the dual purpose of biomass production and ecological values introduced with the 1993 Forest Act. Yet, clearly "productionist" views dominate the debate on forestry in Sweden. Presently, intensification of forestry for an increased biomass production for climate change mitigation is one dominant discourse by the industry and is again moving biomass production as the dominant objective of forest management, overshadowing other objectives. This also aligns very well with Sweden wanting to take a lead in developing bioeconomy – as shown in the analysed national documents. In addition, the institutional mapping for Sweden also revealed a particular view on sustainable forest management, where the continuous and increased production of biomass and wood from Swedish forests where the primary indicator for sustainability, while other measures and the adaption to climate change component of Swedish forests are not emphasized in the Forest Strategy. These findings underscore the importance of the Swedish Innovation Region's Älska Skog 2.0 to educate the public about the interlinkages and importance of the different FES, and to strike a balance between different actors and interests in the forestry sector.

Finland

The maps show that all of the FES recognised to some extent in the Finnish forest strategy, illustrating the multifunctionality of forests in Finland. Wood and bioenergy were the most central FES, but interestingly the maps show that Finland is not a hotspot for wood supply despite forestry being the most important sector in Finland and 73% of the Finnish land is covered by forests. This is due to the fact that per hectare average volumes of timber are low because of intensive management. Although forest management and wood production dominate the national forest policy, there are endeavors to create and market innovative uses of wood and non-wood products for example in super-foods, pharmaceuticals bio-based plastic-substitutes, and other bioeconomy products. Similarly recreation is a central topic in the strategy and forests are something that Finnish people associate with recreational opportunities, but the hotspots for recreation are scarce. This is likely because of the "everyman's rights" and people's tendency to recreate in their nearby forests. Climate regulation hotspots are located mainly in the South in the agriculture intensive area. There is also institutional demand for climate regulation in forests. This is apparent also in the habitat bank innovation region, as climate change and CO2 compensations are at the centre of media and citizen attention in popular compensation discussion. Interestingly, the most prominent hotspots were for soil quality control, perhaps because Finland's soils are peat-rich. Soil and water regulation functions are not centrally reflected in the national forest strategy regarding FES erosion and water protection. Indeed, forests are framed less as having water protection functions in Finland. There are habitat provision hotspots throughout the country, accordingly biodiversity conservation is central in the forest strategy displaying its central role in sustainable forest management for all forest activities.

Italy

In Italy, forest strategies are generally weak, particularly from the perspective of risk control and climate adaptation. With the exception of bioenergy and climate regulation, the maps of FES in forest strategies show that in Italy the presence of FES among the strategies' objectives is lower than in other European countries. This is because management strategies are mainly linked to bioenergy and markets, despite the relatively high levels of actor rights. The aftermath of the "Vaia" storm (October 2018) produced a mobilisation at different levels (from high-level policy-making to actors on the ground), which may have important effects in future forest policy and management. This can have an influence in the Primiero Innovation Region. The IR may in the future provide interesting insights for other regions in Italy, pursuing similar objectives of how to initiate an active dialog with multiple relevant stakeholders and engage them to design suitable measures for maintaining or restoring important forest/pasture ecosystem services (e.g., timber, scenic value, risk control). As shown by the FES maps, alpine settings like that of the IR tend to have a particularly high level of diversity of forest ecosystem services provided. However, the sustainable provision of these FES is at risk, if suitable policies are not implemented. The IR process serves primarily to develop innovative funding mechanisms that support the maintenance of forest management practices on public land, and also support private land-owners in actively managing their interspersed parcels. Combined, this landscape approach to forest and pasture management is expected to reduce future loss of FES and promote their sustainable provision or restoration. Replication of the ideas and mechanisms developing in the Primiero IR may be transferred to other alpine areas that show similar characteristics in terms of FES and forest policies.

Germany

In Germany, the range of FES focused within the analysed national documents was broad due to the different geographical accumulations of various FES hotspots and non-hotspots. The specific strategy elaborations on biodiversity can be interpreted as corresponding to the recent public and political focus on species protection and conservation. The same applies to the concretization in terms of recreational FES which have been especially acknowledged by the national government as increasingly important for the people. This general national development may have a strong influence on the Waldaktie IR and a further development of the Waldaktie 2.0 innovation, as decisions have to be made on the future focus of the governance mechanism in terms of its design as a climate protection tool or an integration of other FES aspects – especially biodiversity and recreation. Thus, generally, the Waldaktie 2.0 innovation refers to the social impacts shown by the maps. However, the facts have probably to be modified regarding to different legal regulations and political developments in individual German states which are not depicted so far. In terms of the FES erosion control, we see a relation to the analysis of the combined data - the trend of biophysical scarcity of ecosystem services being related to FES getting weight in policy – as there are not many erosion control hotspots in Germany but a high specification within the strategy.

In general the maps were seen as informative and interesting displays of the analysis carried out by WP2 and sharing information about forest ecosystem services that not everyone is aware of. It was also discussed with the other WPs in a cross-innovation region meeting and they also expressed that the maps aid in the comprehension of the fuller picture of the context in which the project actions take place. From the different WPs perspective one of the main constraints has been that the maps are not dynamic in the sense of showing temporal changes in policies or biophysical supply.

The maps are still a work in progress and will be further developed for D2.3 "Inventory of innovation types and governance of innovation factors across European socio-economic conditions and institutions".

For InnoForESt the final version of the maps will include pop-up boxes of the IRs with a brief introduction and links to the digital platforms being developed in WP4.

4.2 Statistical analysis of the data sets

Seeking to understand further the possible connections between biophysical supply and institutional demand, we conducted in-depth analysis we conducted statistical analysis across the dataset of 280 FES from all 28 national forest, biodiversity and bioeconomy policies. The aim was to make use of the entire coded national policy document data further and understand coincidence at the country level. The requirement for comparability in this analysis was not as strict as for the maps, in which we only included the comparable 10 forest strategies, and going beyond visual interpretation. Similar analysis has been done for example for the Sustainable Development Goal indicators, which are distinct for each goal, and their interconnectedness, with Spearman rank correlation (Pradhan et al., 2017).

We assessed the geographical coincidence of biophysical FES supply and institutional FES demand with Spearman correlation analysis of the biophysical FES hotspot (percent) for each country and weight in policy for FES in all the national documents (ordinal scale, 0-4). The aim was to evaluate whether the places where the hotspots physically are located would be reflected in the policy documents as FES with central mentions.

We also analysed the correlation of biophysical FES hotspots (percent) and weight in policy on innovations (ordinal scale 0-3) and governance mechanisms (ordinal scale, 0-2), to evaluate whether the abundance of biophysical FES would be reflected in the degree to which policies identify innovations and governance mechanisms.

The Spearman correlation analysis showed a slight trend of biophysical scarcity of ecosystem services being related to FES getting weight in policy – or abundance of FES being related to few mentions in policy (Table 22). All the almost significant (<0.05) relationships were negative and out of the five statistically significant (<0.01) relationships, four were negative. For example, a low level of biophysical pollination supply was connected to little weight in policies placed on on game and recreation, likely because pollination values were highest in agriculture dominated, rather than forest dominated areas. Low level of recreation supply was connected with policy demand for bioenergy and resilience. Low level of soil formation hotspot was related to weight placed on Erosion control in policies – apparently because of the geographical differentiation of these hotspots into peatland rich and mountainous areas.

Climate regulation through carbon storage can be observed as an example of a hotspot indicating FES supply connected to FES demand in policy documents: A low level of hotspots of climate regulation was statistically significantly connected to policies putting less weight on bioenergy and much weight on game. In other words, bioenergy demand does not appear to be driven by high volumes in forests, perhaps because the Nordic countries emphasising it have less volume per hectare.

Looking at the findings the other way around, starting from the policy demand side, we can observe bioenergy policy demand as an example. Weight placed on bioenergy in policies was more statistically significantly related to low level of hotspots of wood, climate regulation and recreation, probably signalling the Swedish and Finnish policies placing emphasis on bioenergy and less on a growing carbon stock. Recreation weight in policies was related to shortage in water supply or pollination hotspots.

Table 22. Spearman correlation of forest ecosystem service supply (percent FES hotspot in country) and national institutional demand for FES (weight in 28 policy documents, 0-4), coefficient and two tailed significance.

FES hotspot	FES weight in policy documents									
	Wood	Bioenergy	Edible plants	Game	Biodiv. conser	Eros & water	Climate reg	Recreation	Cultural heri	Resil
Wood	0,052	-,438*	-0,304	0,144	0,262	0,139	-0,127	-0,102	-0,155	-0,075
	0,793	0,020	0,116	0,466	0,178	0,481	0,521	0,607	0,431	0,703
Water	-0,128	-0,173	0,035	-0,148	-0,123	0,107	-0,01	-0,359	0,116	0,107
Supply	0,517	0,380	0,859	0,453	0,534	0,588	0,958	0,061	0,558	0,587
Erosion	-0,181	0,002	0,040	-0,21	0,187	0,195	0,083	-0,312	-0,157	-0,089
	0,357	0,992	0,840	0,283	0,341	0,320	0,673	0,106	0,425	0,652
Pollination	-0,148	-0,023	0,049	-,390*	-0,168	0,157	-0,092	-0,324	-0,157	-0,153
	0,452	0,909	0,804	0,040	0,393	0,425	0,643	0,093	0,426	0,436
Habitat	0,102	0,197	0,067	-0,089	-0,169	-0,067	0,005	0,151	0,003	-0,237
provision	0,604	0,315	0,736	0,653	0,389	0,733	0,981	0,442	0,987	0,226
Soil	0,098	-0,059	-0,106	0,145	-0,313	-0,346	-0,135	0,184	0,158	-0,032
Formation	0,62	0,765	0,591	0,463	0,105	0,072	0,494	0,348	0,423	0,870
Climate	0,164	-,395*	-0,287	,461*	0,285	0,127	-0,130	0,171	-0,247	0,174
Regulation	0,405	0,037	0,138	0,014	0,142	0,518	0,511	0,384	0,205	0,376
Recreation	0,03	-,416*	-0,314	0,092	-0,058	0,237	-0,187	-0,061	-0,276	-0,353
	0,88	0,028	0,103	0,642	0,769	0,225	0,341	0,756	0,154	0,066

The Spearman correlation between percent of hotspot of FES in a country and innovations and governance mechanisms, showed a slight but rather consistent tendency of policies to identify innovations and governance mechanisms when biophysical FES provision was scarce; most significant Spearman correlations were negative (Table 23). Particularly a low level of wood, erosion control and pollination supply was connected to policies identifying innovations and governance mechanisms. Also a low level of habitat provision was related to innovations and governance mechanisms. In contrast, a high level of soil formation was related to policies identifying governance mechanisms. Out of governance mechanisms, particularly market mechanisms and regulation were connected to FES provision.

Table 23. Spearman correlation of forest ecosystem service supply (percent FES hotspot in country) and innovation stages (0-3) and governance mentions (0-2).

	Innovations in policy documents for all FES (N=204)									
	Innovation					Governance				
FES hotspot	Product	Process	Social and networking	Service	Market rearrangement	Markets	Incentives	Regulation	Collaborative	Information
Wood	-0,074	-0,12	-0,091	-,152*	-,162*	-,221**	-0,122	-,196**	-0,009	-0,053
	0,29	0,086	0,194	0,03	0,02	0,002	0,082	0,005	0,897	0,455
Water supply	0,006	0,117	0,117	0,006	0,024	0,052	0,005	-0,096	,147*	-0,081
	0,929	0,096	0,096	0,931	0,736	0,458	0,948	0,171	0,036	0,252
Erosion	-0,124	-0,099	-0,098	-,190**	-0,046	-,192**	-0,092	-,212**	-0,074	-,269**

control	0,076	0,158	0,164	0,007	0,51	0,006	0,191	0,002	0,294	0
Pollination	-,165*	-,140*	-,179*	-0,135	0,012	-0,105	-0,061	-,202**	-,174*	-0,128
	0,018	0,046	0,01	0,054	0,86	0,135	0,387	0,004	0,013	0,067
Habitat	-0,075	-,164*	-,250**	-0,05	-0,006	-0,088	-0,102	-0,014	-,243**	0,02
provision	0,288	0,019	0	0,475	0,927	0,212	0,146	0,847	0	0,777
Soil	0,136	0,064	0,037	0,115	0,001	,138*	-0,052	0,104	0,068	,182**
formation	0,052	0,367	0,599	0,103	0,988	0,049	0,464	0,139	0,336	0,009
Climate	-0,011	-0,068	-0,035	-0,101	-,167*	-,148*	-0,045	-0,09	0,077	0,052
regulation	0,871	0,334	0,616	0,152	0,017	0,035	0,524	0,201	0,272	0,458
Recreation	-0,044	-,277**	-,179*	-,208**	-,158*	-,241**	-,159*	-,193**	-0,102	-0,077
	0,533	0	0,01	0,003	0,024	0,001	0,023	0,006	0,148	0,274

5. Discussion

5.1 Geographical distribution of FES supply and demand

Our analysis in chapter 4 shows that both the biophysical distribution of FES and the policy targeting FES differ across Europe. In addition to the well documented fine-grained distribution of FES (e.g., Maes et al., 2013), our analysis of FES bundles shows geographical concentrations along the north-south gradient. The northernmost areas provide particularly soil carbon, with strong formation, signalling importance for carbon sequestration. Southern Scandinavia and north-eastern central Europe provide the broadest range of forest ecosystem services, including wood, habitat, soil formation and recreation, signalling multifunctionality. The forests of central European mountains and slopes provide wood and particularly water and erosion control as well as climate regulation. The southernmost European forests support agriculture with pollination and are also important for recreation in the densely inhabited areas. Although there is much variation within these areas, the analysis reveals some geographical context specificity in FES supply, and supports the interpretation of emphasis in policy as well as the emergence of governance and innovation.

In terms of demand for FES, which we analyse through emphasis identifiable in policies, rather than relying on metrics of public demand (Burkhard et al., 2012). This institutional mapping, which constitutes an important novel contribution of the InnoForEST, shows that countries do differ in how much weight they place on different forest ecosystem services in their strategies. However, based on correlation analyses across all the 28 policy documents (chp 4.2) that identify the full range of FES, a statistically significant geographical pattern that would connect FES supply and demand cannot be recognised. Yet, a visual analysis of the maps of the 10 countries whose forest strategies were analysed, shows that for example the mountainous countries' strategies put weight on erosion control (Figure 31a) and water protection (Figure 31b), and Central European and Scandinavian countries put weight on recreation and cultural FES.

5.2 Forest ecosystem services in policy

As for distinct FES, biodiversity conservation is the only FES that is in some form mentioned in all analysed policy documents. This finding is in line with analyses of biodiversity conservation integration into forest policy, showing the strong commitment to integration, even if superficial (Primmer, 2011; Sotirov and Storch, 2018). Biodiversity conservation is not a typical ecosystem service but a rather broad concept that can be interpreted in diverse ways, often signalling precaution and sustainability in policies and increasingly integrating the non-use preservation ideas with uses of biodiversity and ecosystem services paying attention to also social and economic values (Mace, 2014).

The clear emphasis on biodiversity conservation can also be a signal of the different policy areas simply recognising that biodiversity conservation is important and more needs to be done. This echoes the recent biodiversity and ecosystem services assessment and policy tones (IPBES, 2019).

The analysis of policies shows that biodiversity conservation is supported with innovations. Payments for ecosystem services are considered novel, and also other market rearrangement niches can be identified, such as the removal of harmful subsidies. As a more technical niche innovation, some strategies bring up nature-based solutions as alternatives to technology. Biodiversity conservation stands out as a FES relative to which responsibilities and rights can be recognised. As a public good type policy goal, biodiversity conservation is dominantly mentioned to be at the responsibility of public sector authorities. Also industry and land-owners are recognised as having responsibilities. Indigenous rights and the property rights of land-owners are also associated with biodiversity. Governance mechanisms identified in the policies for securing biodiversity conservation cover the full range from regulation and incentives, to collaborative mechanisms and information. The common European regulation of Birds and Habitats Directives stands out as compared to other FES.

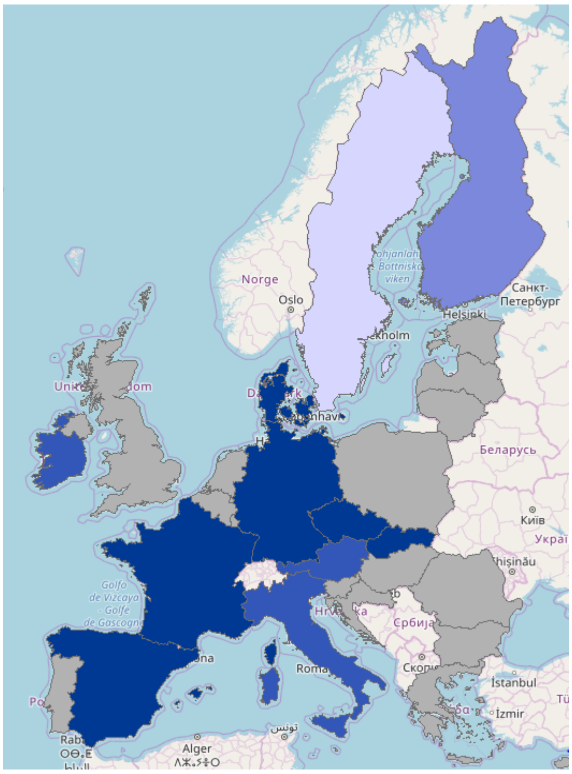

Figure 31a. Weight placed on FES Erosion control in forest strategies.

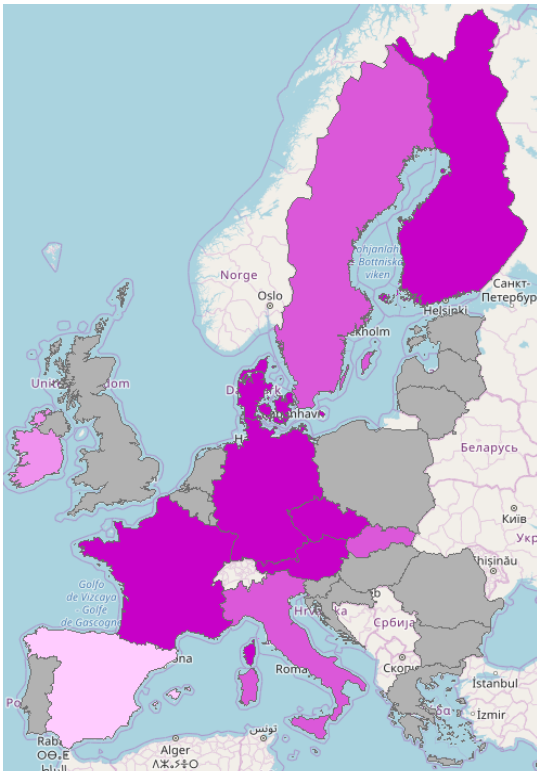

Figure 31b. Weight placed on recreation and culture in forest strategies.

Wood and bioenergy stand out as the focal FES for both forest and bio-economy policies, confirming the earlier findings of European forest policies being focused on wood production (Winkel and Sotirov, 2016). The stated purpose of many of the analysed strategies is to sustainably manage natural resources. Indeed, provisioning FES clearly dominate the forest and bio-economy strategies. The strong role of biomass, either as wood or bioenergy is shown also in the analysis of innovations and governance. Of the clear mentions on product and process innovations, wood clearly dominates, with much emphasis on its renewable character and sustainability as a raw material and fuel. New product ideas are about wood and biomass, sometimes recognising a long value chain.

Also networking innovations and market-based rearrangements centre on procurement of raw material, recognising the responsibilities and rights of industry and land-owners. Industry is recognised also to hold rights to the side streams of wood processing. The new governance mechanisms for wood and bioenergy are justified with sustainability and seek to address climate change and biodiversity conservation, clearly responding to social demand (Toppinen and Korhonen-Kurki, 2013; Kleinschmit et al., 2014). Regulation governing wood is also for securing a level playing field and collaboration and information support coordinated access to markets.

We expected that the documents that mentioned either social innovations and (Kluvankova et al., 2017) or collaborative governance mechanisms (Paavola and Hubacek, 2013), would also address actors' responsibilities. This assumption was based on not only the nature of the innovations and governance mechanisms but also the policy document quotes. However, we did not observe this kind of a relationship. Indeed, actor rights and responsibilities relate most to the responsibilities of those actors who have participated in the policy document formulation, which signals that addressing others' rights and responsibilities is challenging in this kind of strategy documents. This vagueness is in line with more general findings about forest strategies and their goals (Winkel and Sotirov 2016).

Out of regulating ecosystem services, erosion control and climate regulation are clearly recognised particularly in forest strategies, signalling the general attempt to integrate policy goals in the forest sector (Winkel and Sotirov, 2016; Bouwma et al., 2018). Also resilience, particularly in the face of climate change is recognised but not across the board. The emergence of climate issues in forest policy is signalled by climate change mitigation related innovations and new governance mechanisms, such as market-based instruments, new regulation and standards as well as collaboration and networking. Also some references are made to climate change adaptation type activities for anticipating and managing increasing risks.

Cultural ecosystem services are not as uniformly spelled out in the analysed strategies as provisioning or regulating FES. Yet, recreation is recognised in many forest strategies. Of the few mentions for innovations and governance relative to recreation, most are related to recreation infrastructure and accessibility. These policies recognise the importance of engagement and collaborative planning as well as information provision, as is typical of ecosystem services governance (Primmer et al., 2015; Saarikoski et al., 2018), and they also connect these to the responsibility of the land-owners to provide recreation. Citizens' rights to recreation are connected to public views on some particular uses of forests, like hunting, and also to forests providing wellbeing.

5.3 Connection between FES supply and demand

Public policies are designed to secure public goods, and environmentally and sustainability-oriented policies have this kind of motivation particularly strong (Wurzel et al., 2013). It could be assumed that policies would emerge in contexts where there is an identified problem or scarcity. With our analysis combining data on FES provision across the European landscape and document analysis of European forest, biodiversity and bio-economy policies, we show that there indeed is a tendency in policies to address scarce forest ecosystem services. From our Spearman correlation between percent of hotspot of FES in a country and innovations and governance mechanisms mentioned in strategies, we observe a slight but rather consistent tendency of policies to identify innovations and governance mechanisms when FES are scarce. The correlation analyses, and the maps should be interpreted carefully, with our detailed analysis because the strategies we have analysed communicate goals only at a country level.

5.4 Remarks on the mapping analyses and method

Our analysis illustrates the challenges and opportunities of combining detailed quantitative and qualitative analysis. The geographical detail in the biophysical FES supply analysis generates an expectation for a similar type of an understanding for policy demand. Yet, policies are formulated at rather large spatial scale, often at a region or national level. Even if more fine-grained policy exists, e.g. at a municipality level, it will not be comparable across countries. Comparability has also forced us to develop a rather rigid coding protocol, to be able to produce a coherent database from the policy coding. In the process of our analysis, we have iterated the benefits and limitations of fine detail and general categories, starting from how we defined FES for the biophysical analysis and the document analysis, and ending up with the combined maps illustrating the biophysical FES supply and institutional FES demand.

The documents that would serve as data sources and the approach of coding and analysing the ecosystem service related to innovations, actors and governance were decided after trying out and discussing different approaches among the WP2 project partners. This allowed us to design a simple map and user interface that aligns with the biophysical mapping, and to analyse the biophysical supply of FES and policy demand for FES across Europe. Alternative approaches would have taken the actors or innovations as a starting point or deriving the analytical categories from the InnoForESt case studies. These other approaches were discarded as they were covered by the other WPs within the project.

Using webropol survey format for coding the policy document analysis works well, given that there are resources for coordination, support and calibration. In this analysis, support filling in the database questionnaire was provided throughout the process and the questionnaire had spaces for expressing uncertainties and doubts. On average, it took 2 to 3 days for a person to analyse one policy document. The time needed was influenced by the length of the document, the language and the analyser's previous familiarity with it. We asked people to share their experiences on the analysis process via email.

For some team members was more challenging to analyse documents that had scarce mentions of the forest ecosystem services inquired while some found it more challenging when there were multiple mentions of the FES and other factors and it was not clear how they were linked. Evaluating the weight or importance of the factors was difficult since the documents varied on the ways they expressed importance or presented central factors. Making interpretations that would not be influenced by the analysts' previous knowledge or personal perceptions was an acknowledged challenge. The analysts' included people from the project consortium but also people less familiar with the InnoForESt project or WP2 activities. However, the analysis was completed by people who participated in the training and planning of the questionnaire and people who solely followed the instructions of the manual.

As part of this deliverable we provide a database that can be accessed and used by all InnoForESt partners and Work Packages and will be made open access. The biophysical maps will be made available in image format (e.g. .jpg, .pdf) via the InnoForESt website to open publicly share information about the location and the quantity of different FES provided across Europe. The analysis framework for the finer scale analysis of governance of policy and business innovation types and conditions in WP3 aligns with the mapping as drafted in this report. Moreover, we plan to further test the InnoForESt innovations together with WP4 innovation platforms and WP5 innovation process based also on the information generated in WP2. The maps will be presented to the innovation teams and their views on the emerging ideas and potential uses for the maps will be collected and discussed with the innovation teams and the science partners involved in WP4 in the upcoming annual meetings in 2019.

5.5 Future use of mapping output

The database and the combined maps will be further iterated with the innovation regions, to explore to what extent their biophysical and institutional context shapes their particular innovation, as compared to other regions. The Innovation Regions can explore whether they are able to identify similar contexts with differing innovations to stimulate potentially replicable ideas, or whether there is an opportunity to upscale their own innovation and what favourable context is needed therefore. These outcomes will be communicated to WP6 to provide a basis for analysing replicability and upscaling, and for deriving at policy and business recommendations.

Activities in the case study areas can be described in detail and “pinned” onto the maps and possibly used as points of evaluation of how the ecological-institutional condition might host innovation. Using the biophysical and institutional mapping, we can identify niche innovations for further co-learning. This report does not contain explicit analysis between the different IRs or countries and the European context, but these differences can be easily interpreted by looking at the maps in connection with this deliverable and should be analysed in the final deliverable of WP2.

The database on institutional factors can be used to analyse the coincidence of FES, innovations, actors, and governance approaches in the analysed policies as well as the specific framings for these factors.

Also other datasets could be overlaid with the two datasets. For example, an overlay of biophysical maps and maps of population distribution and density may help detect potential mismatches between the demand and supply of FES. The combined analysis of biophysical and institutional data as presented in this report may require information on land ownership, given the different management and governance approaches that are possible in public versus private lands.

Ideally, trends in FES supply and demand can support the analysis of governance and innovations, also from a temporal perspective, which we have not conducted in this analysis. The biophysical maps we present do not consider temporal aspects owing to the amount of data, the respective analysis and the matching that would be required to assess the past evolution in ES provision. An additional limitation to do this is the highly complex modelling that would be required to estimate future ES provision based on the current situation and expected changes in natural resource management and urbanization trends in Europe. The evolution of innovations and their institutional context will be analysed in each Innovation Region in WP5.

6. Conclusions

Our analysis illustrates that both the biophysical distribution of FES and the policy targeting FES differ across Europe. The analysis of biophysical FES supply through bundles shows that biophysical FES tend to be related to the climatic-ecological gradient, with cultural-agricultural FES being concentrated in the Mediterranean area, wood and water FES in the central area, soil carbon FES in the northernmost area and a mix of all FES in the north-eastern area. In terms of demand for FES, our analysis shows that countries do differ in how much weight they place on different FES in their strategies. Wood and bioenergy stand out as the focal FES for both forest and bio-economy policies, while biodiversity conservation is the only FES that is in some form mentioned in all analysed policy documents. The documents identify innovations, actor roles and governance mechanisms in detail for those ecosystem services that they directly address. The analysis of policies shows that biodiversity conservation is supported with innovations. New product ideas are about wood and biomass, sometimes recognising a long value chain. Also networking innovations and market-based rearrangements centre on procurement of raw material, recognising the responsibilities and rights of industry and land-owners. With our analysis combining data on FES provision across the European landscape and document analysis of European forest, biodiversity and bio-economy policies, we show that there is a slight tendency in policies to address and detail innovations and governance for scarce forest ecosystem services.

By analysing how different EU, national and regional policies address different forest relevant innovations, governance mechanisms and actors our analysis provides a deeper understanding of the biophysical-institutional landscape that can condition innovation in the forest sector, and ideally, identify opportunities for transferring and upscaling innovations (Objective 3 of InnoForESt).

Knowledge about where the different FES are located across Europe is important, since it is expected that they are governed spatially and seeing how and if the supply of the FES meets the political demand set out in EU level and national forest policies is the objective of our combining the biophysical and institutional data. We take this assumption seriously. As a response, we have developed a novel approach to analysing FES supply and demand in parallel, through overlaying and correlating the biophysical supply of forest ecosystem services and the institutional demand as expressed in policy documents. The approach supports innovation transfer, and it should be critically tested and further developed, to overcome the challenges related to scale, temporal limitations and general usability and interpretation of these types of overlaid maps.

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ANNEXES

ANNEX 1 DATABASE PROTOCOL version 2.0

INNOFOREST DATABASE

Welcome to the database questionnaire! It will help getting an overview on Forest Ecosystem Services and innovations in this very field across Europe, through document analysis. Please fill in the questionnaire document by document and ecosystem service by ecosystem service.

Please read the manual before answering, it will provide you with important information on each question of the questionnaire.

The purpose of this institutional mapping is to gain an understanding of the institutional structure of Forest Ecosystems across Europe and in the case study regions. This is to support the more detailed analyses, comparison and upscaling in the project. The questionnaire is part of task 2.2 on InnoForESt.

We thank you for your time and commitment!

P1: BACKGROUND INFORMATION ON THE DOCUMENT

Since the questionnaire is filled in for each FES, even if not mentioned in the document, you will be filling in this questionnaire a total of 10 times/document.

The background information on this page should always be filled in completely when you are filling in the questionnaire for the first time relating to a certain document. The following 9 times you can only answer Q1 "Document name" on this first page and we will automatically fill in the rest of the background information after you have completed the questionnaire for all FES. So you submit after each FES, and start a new survey for the next FES. **Be sure to fill in the name in the same format since it is the identifier for us when completing Q2-13!**

1. Document name

____

2. Year published

[DROP MENU YEARS 1900-2018]

3. Document type

( ) Strategy
( ) Law
( ) Act
( ) Manual
( ) Programme
( ) Other, what: ________________________________

4. Entity responsible for document

____

5. Geopolitical coverage of the document

[DROP MENU]
Regional
National
EU
European
International

6. Country

[DROP MENU EUROPE]

7. Types of forest management systems in the area that the document covers. Please mark the dominatin

Clear-cut, even-aged stand	YES	NO	DOMINATING	IDK
Clear-cut with retention trees	YES	NO	DOMINATING	IDK
Clear-cut with retention habitats	YES	NO	DOMINATING	IDK
Continuous cover forestry / selective single-tree removals	YES	NO	DOMINATING	IDK
Coppice	YES	NO	DOMINATING	IDK
Close-to-nature management	YES	NO	DOMINATING	IDK
Afforestation (new plantations, e.g. on former agricultural land)	YES	NO	DOMINATING	IDK
Agro-forestry (e.g. wood pastures and shelter trees)	YES	NO	DOMINATING	IDK
Other, what:______________________	YES	NO	DOMINATING	IDK

SAVE AND CONTINUE LATER BUTTON

8. Are there clearly new forest management systems mentioned in the document, and if yes, please describe:

( ) No
( ) Yes, specify

____

____

9. Stated purpose of the document

____

____

____

SAVE AND CONTINUE LATER BUTTON

10. Does this document follow or replace a previous document addressing the same topic? If yes, please specify the preceding document and its publishing year.

( ) No
( ) Yes, please specify (name and year): ___________________________________

11. Is the phrase "ecosystem service(s)" mentioned directly and/or through benefits and values provided by forests for humans

( ) No
( ) Yes, please specify (quote): ____

P2: FOREST ECOSYSTEM SERVICE ANALYSED

Reminder: Each ES as one questionnaire completed ->
submit and then fill next FES

12. Forest ecosystem service type

[DROP MENU]
Wood
Bioenergy
Edible plants and other non-wood forest products: berries, mushroom, cork, other
Game
Biodiversity conservation
Erosion and water protection
Climate regulation, carbon sequestration and stock
Recreation: cultural, physical and experiential interactions
Cultural heritage
Resilience (risk control and climate change adaptation)

SAVE AND CONTINUE LATER BUTTON

13. How is the forest ecosystem service addressed in the document? You may use a quote to specify.

____

____

14. Weight or importance given to the ecosystem service in the document

( ) 0= No mention
( ) 1= Mentioned indirectly
( ) 2= Mentioned directly but not an objective
( ) 3= Stated as an objective but no stated targets or measures for implementation
( ) 4=A central objective with clear targets and measures for implementation

If you have answered "0= No mention" to the previous question (Q14) you may skip to the submission page of the questionnaire and submit your answers. No need to fill in the rest of the questionnaire.

15. Other forest ecosystem service class related to the FES being analysed

[TICK BOXES]
Wood
Bioenergy
Edible plants and other non-wood forest products: berries, mushroom, cork, other
Game
Biodiversity conservation
Erosion and water protection
Climate regulation, carbon sequestration and stock
Recreation: cultural, physical and experiential interactions
Cultural heritage
Resilience (risk control and climate change adaptation)

16. Other documents, policies etc. mentioned as relative to the management of this FES

____

____

P3: INNOVATIONS

17. Are there innovations related to this forest ecosystem service? If yes, how are the innovations expressed?

( ) No
( ) Yes, please specify: ______________________

SAVE AND CONTINUE LATER BUTTON

18. How would you classify the innovation stage and type?

Key for the scale (also briefly above the numbers in webropol):
0=No mention
1=Promoting (promoting, R&D, planning)
2=Implementation (piloting, allocating responsibilities, resources, to activities)
3=Upscaling (significantly adding resources and responsibilities, e.g. to a new area)

PLEASE SPECIFY

Product innovation 0 1 2 3
Please specify:_________

Process innovation and technology 0 1 2 3
Improvements
Please specify: _________

Social innovation and networking 0 1 2 3
Innovation
Please specify: _________

Service innovation 0 1 2 3
Please specify: _________

Market rearrangement and 0 1 2 3
institutional innovation
Please specify_________

Other, what: _______ 0 1 2 3

SAVE AND CONTINUE LATER BUTTON

P4: ACTORS

19. Actors and their responsibilities in relation to this FES

Scale for the role given to the actor in relation to the FES in the document being analysed *(also briefly above the numbers in webropol)*
0=not mentioned
1=indirectly mentioned
2=clearly mentioned but with no clear responsibilities
3=mentioned and responsibility clear
4=Central responsibilities

Public administration 0 1 2 3 4
European 0 1 2 3 4
EU 0 1 2 3 4
National 0 1 2 3 4
Regional 0 1 2 3 4
Local 0 1 2 3 4

Forest and wood using business and industry 0 1 2 3 4

Forest related service business 0 1 2 3 4

Associations, NGOS and CS actors 0 1 2 3 4

Landowners 0 1 2 3 4

Recreational users 0 1 2 3 4

Citizens 0 1 2 3 4

Educational bodies 0 1 2 3 4

Research institutes	0	1	2	3	4	
Financiers	0	1	2	3	4	
Other, specify:_______________		0	1	2	3	4
Other, specify:_______________		0	1	2	3	4
Other, specify:_______________		0	1	2	3	4
Other, specify:_______________		0	1	2	3	4

SAVE AND CONTINUE LATER BUTTON

20. Actors and their rights in relation to this FES

Scale for the rights given to the actor as beneficiary of the FES in the document being analysed *(also briefly above the numbers in webropol)*

0=no direct reference to rights
1=clear mention of rights but not clear whether there is a need to develop them
2=clear mention of rights that need to be maintained or strengthened

Public administration TXT BOX	0	1	2	
Forest and wood using business and industry		0	1	2
Forest related service business		0	1	2
Associations and Civil society actors		0	1	2
Landowners	0	1	2	
Recreational users	0	1	2	
Citizens	0	1	2	
Educational bodies	0	1	2	
Research institutes	0	1	2	
Financiers	0	1	2	
Other, specify:_______________		0	1	2
Other, specify:_______________		0	1	2
Other, specify:_______________		0	1	2
Other, specify:_______________		0	1	2

SAVE AND CONTINUE LATER BUTTON

P5: GOVERNANCE MECHANISMS

21. Governance mechanisms mentioned related to the FES

Scale for governance mechanisms *(also briefly above the numbers in webropol) Specify not compulsory.*

0= no reference
1=clear mention but not clear what development is expected
2= clear mention that will be developed

Markets (for ES provision: private-to-private with or without intermediaries, market-like arrangements 0 1 2
SPECIFY:________________________

Incentives by government 0 1 2
SPECIFY:________________________

Regulation ((other) laws, statutes) 0 1 2
SPECIFY:________________________

Collaborative and distributed (networks, cooperatives) 0 1 2
SPECIFY:________________________

Information (guidelines, information technology and platforms, extension and advice) 0 1 2
SPECIFY:_________________________

Other, what: _______________________ 0 1 2

SAVE AND CONTINUE LATER BUTTON

22. Are there clearly new governance mechanisms related to this FES mentioned in the document. If yes, please describe them:

( ) No
( ) Yes, specify

____

____

23. Open text box for unsure questions, quotes etc.

____

____

____

____

Remember to always submit and only then start again for the next FES!
This way we will get the data right in the output sheet.

SUBMIT
If you are going to code a new FES, submit this form and start a new one by clicking freshly the link.

ANNEX 2 MANUAL FOR DATABASE QUESTIONNAIRE

INSTRUCTIONS FOR FILLING IN THE INNOFOREST T2.2 DATABASE QUESTIONNAIRE

Read the manual **BEFORE** reading and coding strategies for filling in the database questionnaire. Note! Some words in this document contain links to websites or other documents that provide more information.

In addition to this manual the following documents have been provided to help you fill in the database questionnaire:

1. Clean version of the Webropol questionnaire in .docx format
2. Example of a .docx with the FES Wood filled in based on the EU Forest Strategy
3. Example of a .docx with the FES Bioenergy filled in based on the EU Forest Strategy
4. Excel sheet of strategies being analysed / institution

We encourage you to always ask via email or by comments in the questionnaire if you have uncertainties about anything!

Glossary

CICES	The Common International Classification of Ecosystem Services
ES	Ecosystem service
EUFS	European Forest Strategy
FES	Forest Ecosystem service
FNFS	Finnish National Forest Strategy 2025
FMA	Forest Management System
IDK	I don't know
Q	Question

1. General instructions

Before filling in the database questionnaire we ask you to first read through the whole document based on which you will fill the questionnaire. This allows you to get a general overview of what stands out or seems highlighted in the document. Upon this first reading you may want to take some notes about the highlights or copy certain quotes that reflect what you have felt as important in the document. After this first read, it might also be easier to fill in the questionnaire without getting too stuck on evaluating the mentions and weight of importance given to things.

We wish that the first document analysed would be *national forest strategy or forest act* of your country or region. This will give us also an idea about how much resources one document takes and help us prioritize what other documents should be analysed from each country. Thus far we will most likely ask at least the analysis of Bioeconomy strategies and Biodiversity (Nature conservation) strategies.

SYKE will do the analysis of the EU documents.

We would also ask you to fill in the table (link to excel) stating the document(s) that you have already analysed or a planning to analyse in order to avoid double work.

Take the document you are analysing as a starting point and do not make inferences outside it (other than in Q7 on forest management systems and Q23 in which you can relate what you have read in the document to what you know from other sources.

Fill the questionnaire always based on one document (strategy or law) and one forest ecosystem service (FES) at a time. Thus you will need to fill in the questionnaire several times based on the one document in order to go through all the FES that we have listed (currently 10 options). So you submit after each FES, and start a new survey for the next FES. (No option to copy the background information (Qs1-12) automatically is available in Webropol, but when you fill in the questionnaire for the second and following times, it will be enough that you just answer Q1 "document title" (make sure the title is identical), and we will fill in the rest in the output sheet). Keep in mind that our primary interest is on ecosystem services *related to forests*, so the categories about the ES that come up in the questions have been chosen accordingly. T2.1 of biophysical mapping and the CICES classification of ES has also been used when deciding on the classes.

One option is to analyse the document with several copies of the survey open at the same and keep one as the master. It is a good idea to start with the most apparent FES that the strategy addresses (e.g. wood, or biodiversity).

NOTE: *Fill in the questionnaire also regarding the FES that are NOT mentioned.* These data allow seeing what FES are not explicit in the documents, and will be valuable information for us. Thus we ask that you always fill in the questionnaire until Q14, which when answered "not mentioned" will allow you to leave the rest of the questionnaire blank. An automatic "jump" rule has been inserted into the option "not mentioned" that will lead you to the last page of the questionnaire where you can submit your answers. ALWAYS SUBMIT, even if there is "no mention".

Many of the attempts to fill in the questionnaire will result in largely empty outputs because the documents do not have relevant content, especially when analysing other documents such as Bioeconomy strategies etc. that might not mention forest ecosystem services explicitly at all. This is fine.

If you are unsure about whether things are "hinted at", you may put quotes and questions at the end of the survey in the Q22 open text box or via email to the InnoForESt team (liisa.varumo@ymparisto.fi; eeva.primmer@ymparisto.fi)

If you have assisting staff conducting the analysis, be prepared to talk through the analysis with them and preferably allow the one person to do all the documents from your country / region. It is mainly the science partner who is responsible for completing the document analysis.

The questionnaire allows you to "save and continue later" between the sets of questions. Copy the link the questionnaire gives you after you have saved for continuing later, and save it (ie. email it to yourself), so you can start where you got left.

After the questions there are also small help- boxes marked with "?" that appear when you hover the mouse over them giving more information and instructions on what is relevant for the question.

If you wish to test filling in the questionnaire, please write "TEST" at the beginning of Q1 document title so that we know to remove the data row afterwards.

The questionnaire is not filled in anonymously to allow follow-up and clarifications when necessary. Only one responder per strategy is required.

2. Some practical tips (Liisa's and Eeva's experience)

Tip: Might be practical to not fill in the webropol while reading the document, rather fill in the questionnaire on the word document and then just copy+paste into the webropol. This way you can fill in all the ES from one document on one read into for example separate word files and then fill the webropol several times based on all the ES copy+pasting from word. This might be particularly helpful with forest strategies (and forest laws) because they are the ones that have more information to be included in the database.

If you have a printout, you can choose to use coloured pens and:
Highlight with one colour all the FES (or even use a different colour for each ES)
Highlight with one colour all the actors. If you are analysing the electronic document you can mark the ES with margin comments:
Use consistently the same word for the same ES (e.g. "wood" or "biodiversity" (this way you can search also your comments), and same actors.

Always when looking for a response to a specific question we advise also to check with Ctrl+F the key words of the question from the document. E.g. When searching for the FES bioenergy: ctrl+F "bioenergy" and see what comes up. Additional keyword search tips are given below to many of the questions. Note different spellings of words, e.g. "bioenergy" and "bio-energy" and other possible references to the same topic, e.g., "energy", "biofuel", "fuel".

For non-forest strategies (e.g. BD, bioeconomy strategy) search the document with any forest related terms (ctrl+f "fores*" "wood" etc.) and then analyse those bits in relation to the questionnaire.

3. Interpret words broadly: novel, new, innovative

There are questions about new or novel forest management systems, innovations and governance mechanisms (Qs 8, 16, 21). The interpretation of what is meant by "new" or "novel" can be as simple as whether the document uses one of these words with reference to the FES, actor, management type, investment etc. Newness can also be indications of upcoming changes, aims or trends or activities that are going to be implemented according to the document.

Interpretations of whether something is new do not need to be made in terms of new compared to something.

The word "new" 194 mentions in the Finnish Forest Strategy

4. **The word “innovation”**

Schumpeter (1911) defines innovation as a continuously occurring implementation of new combinations of means of production. Nelson and Winter (1977), in their institutional analysis, define technological innovation as a non-trivial change in products and processes where there are no previous experiences. Often, innovation denotes successful introductions of novelties. Innovation is the development and implementation of new ideas by people who over engage in transactions with others within an institutional setting (Van de Ven 1986).

5. **Rights (Q20)**

Rights to ecosystem services can be explicitly defined e.g., in law, or they can rely on customs routines professional norms or other informal institutions. This means that rights are often not directly stated, and we need to interpret them from references to actors’ relationships with ecosystem services and their governance. Basically, we are looking for statements that express that actors have a right to benefit from the ecosystem (Rinne and Primmer, 2015), or to access, use, manage and make decisions about them (Schlager and Ostrom, 1992).

QUESTION SPECIFIC INSTRUCTIONS

These instructions will include some examples to help evaluate what options to choose when questions have scales from 0-4 and also some “hint” words and expressions as to interpreting if something is mentioned or not and what weight should be given to the expression.

We suggest starting the filling process with the FES that you find most central to the document analysed.

These instructions contain illustrative examples from the Finnish National Forest Strategy 2025 (FFS) and the EU Forest Strategy (EUFS). Additionally filled in examples of the EUFS for the FES Wood and Bioenergy have been provided to you as .docx files.

Upon answering the questionnaire stick to the information provided by the document and avoid over-interpreting, even if you feel that you have a strong knowledge about the topic in question. Only in Q7 if you have personal knowledge about the FMSs please share it. When in doubt about relevance of something we encourage to write it down in the open text boxes or email us to think of the uncertainty together.

In all the questions with ratings you will <u>always need to first choose the rating</u> (from 0-4) before you will be able to write in the open text box.

Qs 1-11 Background information on the document

Q1: In the document name remember to also put the years for which it applies if they are stated in the title.

Write the document name identically for each round you fill in the survey (for each FES).

Q8: The question relates to forest management systems (FMS) <u>in the geographical coverage of the document</u>. Thus if you are reading a national strategy, this means FMS in your country, whereas if you are reading a regional strategy, this refers to FMSs in the region.

The forest management system(s) might not be mentioned in the document. Even if you know them through other sources, you should mark them. Also if all of the FMSs are applicable, please (try) to indicate the dominating (1-2) one(s). If you don't know the FMS in the area, mark "IDK". (The background knowledge you have, applies to all the documents representing the same country/region.)

Ctrl+f tips: Clearcut, even-aged system, uneven-aged system

Q9: See interpretations of novel in chapter 3 above. This question is especially interested in changes in FMSs.

Ctrl+f tips for novel: new, diversif*, explor*, devel*

Q10: The stated purpose of the document – question is used to link or find justifications as to why this document is relevant in the institutional mapping of forest ecosystem services innovations. It may also reveal whether the document is relevant to forest policy in general. You can include a direct quote but if the purpose is very long (e.g. 10 points), try to summarize. Put quotation marks "like this" around every direct quote and add the page number of the quote.

Q11: This question aims to give an idea of how often the strategies and policies are changed in different European countries. It may give indications of the importance of the sector, stability of policies and reactions to trends, developments and influences.

Note: For the next rounds of filling in the questionnaire based on the same document you may respond only to Q1 and we will fill in then Qs 2-11 in the output excel after you have submitted all your answers.

Qs 12-16. Forest ecosystem service analysed

Q12: Pay attention to <u>forest</u> ecosystem services only. The type (section) of service (i.e. provisioning, regulating and cultural) is derived from the CICES scheme. Hence, game, for example, is presented as a provisioning service because it refers to the maintenance of game populations in the forest rather than recreational hunting (which would be a cultural service). However, if you wish to comment that the document mentions a direct link or categorizes one ES under several types, you may do so in Q15.

<u>Ctrl+f tips (besides the ES itself):</u>
Wood: timber, woody biomass
Note: new textiles, chemicals etc. aren't considered FES since they have been highly processed and distanced from being forest ecosystem services.
Bioenergy: "wood-based energy", "biofuel", "biomass",
Edible plants and other non-wood products, berries, mushrooms, cork, sap
Game
Biodiversity conservation: *(here you may also mark if protecting forests is mentioned)*
Erosion and water protection
Climate regulation, carbon sequestration and stock
Recreation: cultural, physical and experiential interactions
Cultural heritage: "Landscape", "rural", "lifestyle"
Resilience: risk control and climate change adaptation: "mitigat*"

Note the difference between "climate regulation, carbon sequestration and stock", and "climate change adaptation"

Q13: Please add quotes (with quotation marks "like this") about the mention of the FES to support the evaluation you make on the qualitative weight expressed as an ordinal scale (0-4) in the following Q13.

<u>*Example on bioenergy from FNFS:*</u>
"The production of bioenergy and biochemicals based on forests and wood will grow" (p.46)
"As the target for forest chip use by 2020 has been set 25 TWh, equalling some 13 million solid cubic metres (m3) of forest chips a year" (p. 14)
"Production of domestic wood-based energy increases" (p.19)

Q14: This question is related to how important or central you analyse the FES to be in the document. Weight is not limited to economic weight or importance of the FES.

Weight given to FES examples and hint words/expressions:

Examples for the rating. Take the "strongest mention" as the ending point.

1= Mentioned indirectly
Example FNFS for erosion ~~and water~~ protection:
Climate change may also influence the erosion vulnerability of soil, and thus the pollutant load from forestry.(p.27)

Example biodiversity conservation EUFS:
Protect forests and biodiversity from the significant effects of storms and fires, increasingly scarce water resources, and pests. These threats do not respect national borders and are exacerbated by climate change.

2= Mentioned directly but not an objective
Example FNFS for edible plants:
The total value of traditional natural products – berries, mushrooms and game – also amounts to hundreds of millions of euros annually. They are an important by-product of the forests, both economically and socially. (p.15)

3= Stated as an objective but no stated targets or measures for implementation
Example from FNFS for bioenergy:
"Production of domestic wood-based energy increases" (p.19)

4=A central objective with clear targets and measures for implementation
Example from FNFS for Biodiversity conservation:
"Both conservation areas and nature management in commercial forests are needed to safeguard biodiversity in the forest environment. These measures also include restoration in compliance with the biodiversity strategy. Restoration of mires that are unsuitable for forestry should be a particular focus area. The management of commercial forests plays a key role in fostering biodiversity, as some 90 of our forests are available for forestry use." (p.27)

This may also include promoting investments, tai ctrl+F "Promote" (use, raw material), "stimulate"

Q15: Other related FES: mark those that are somehow <u>clearly</u> connected with this FES (not indirect mentions).

Q16: Here you may mention documents that are mentioned in the document you are analysing. Thus if e.g. Action Plans for the implementation of the strategy under analysis are mentioned, please not them and other relevant document here.

Qs 17-18 Innovativeness

See above chapter 4 definition of innovation. Also keep in mind Qs 21 & 22 about governance mechanisms when answering this question. Some of the innovations may apply to new governance mechanisms as well and you may want to note this in Qs 21 & 22.

Q17: In this question you may put a quote or in your own words justify why the FES is innovative. For the next question Q18 you may insert specific quotes or your own words to express certain types of innovations.

Q18: Types of innovation and their stages 0-3

Example of Product Innovation*: e.g. new woody biomass-based packaging materials (with FES wood)*

Example of Process Innovation and technology improvements *e.g. new bioenergy energy processing technologies (FES bioenergy), new internet platforms for ecotourism (FES recreation)*

Wood: "prioritise investments in: modernising forestry technologies;"

Example of Social process and networking innovation, *e.g., new forums, working groups, platforms for engaging actors (any FES)*

Example of Service Innovation: *e.g. new data management systems, new training or extension services (any FES, e.g. bioenergy, biodiversity)*

Example of Market rearrangement and institutional innovation: *e.g. development of a payment, offsetting or banking mechanism (any FES, e.g., climate regulation)*

Note. Version 2: Previously the stages were from 0-4. The category "visioning" has now been removed (merged with "promoting").

Qs 19 and 20 Actors

There are two questions in the actors section – one related to RESPONSIBILITIES and the other to RIGHTS

In these questions all alternatives (rows) should have a tick, since we also want to see the "not mentioned" actors.

They are not selected as default because we want you to read through each of them and tick the role of the actor.

The option in bold is a higher category and what comes below are subcategory options from which to choose and for which to mark a role. Always tick a role for the higher category. At the end of the list there are currently 4 slots to specify actors that don't fit in the given categories.

An empty space for specification will be left after each actor for additional comments or remarks.

Q19: Examples of responsibilities scale:

How to deal with actors that have a role in preparing the document? Not necessarily role in any specific FES.

1=indirectly mentioned

2=clearly mentioned but with no clear role

3=mentioned and role clear
Example in climate regulation for several actors (FNFS 36) listed in a box as "other actors":
Finnish Forest Centre, Finnish Forest Association, Natural Resources Institute Finland, universities, Finnish National Board of Education, nature and environment schools, NGOs, actors in the sector

4=A central responsibility role
Example for recreation and role of Associations and civil society actors:
NGOs play a key part in achieving the targets related to the recreational and well-being use of forests and developing citizens' relationship with the forests. (FNFS p. 29)

Note. Version 2: The sub- categories of the actors have been removed from all categories except "Public administration"

Q20: Actor's rights.
Here the lower categories have been replaced by open text boxes where you may specify the actor. You can list several actors in the same box, separate them with a semicolon or you may also use the "Other, what" box at the end.
Consider all types of rights; access, property, use and management rights. Also see section 5 "Rights".

Examples of rights scale:

1=clear mention of rights but not clear what development is expected:

Example recreation FES for citizens and tourists:

"...societal benefits, including for human health, recreation and tourism" (EUFS)

"The accessibility of forests also plays a key role in building and keeping up a relationship with the forest; in this respect, local forests used by day-care centres and schools are of vital importance." (FNFS p. 29)

2=clear mention of rights that need to be maintained or strengthened

Example climate regulation for industry:
"Respond to the challenges and opportunities that forest-based industries face in..., climate policy" (EUFS)
Example wood for industry:
"Stimulate market growth and internationalization of EU Forest-based Industry products" (EUFS)

Note Version 2: The ordinal scale regarding actor's rights has been changed from 0-4 to 0-2.
- Previous "1=indirect mention" has been removed (merged with mention of rights).
- Previous "2" has been changed to "1= mention of rights but not clear whether there is a need to develop them"
- Previous 3 and 4 have been combined to current "2=clear mention of rights that need to be maintained or strengthened"

Qs 21 and 22 Governance mechanisms

Note1. Version 2: The ordinal scale regarding stages of governance mechanism has been changed from 0-4 to 0-2.
Previous “1=indirect mention” and “4=clear mention that will be developed into and innovative mechanism” have been removed.
Note2. Version 2: The category “disruption” has been removed from governance mechanisms since it was very rarely mentioned in the documents already analysed. You may however add it in the “other, what?” section or in Q22 if necessary.

Q 23 Open text box

Here you may add any quotes, questions or uncertainties meaningful for T2.2. Also if you feel that something highly important for the mapping is expressed in the document that does not fit into the above questions, you may mention it here.