COST Action “Integrated DSS for delivery of ecosystem services based on EU forest policies” (DSS4ES), WG 1 Report of Task 1.1

Investigation of data for decision-support in forest-related natural resources management – with a focus on spatial data on European and national level

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WG 1 Leader: Dr. Janina Kleemann
Martin-Luther-University Halle-Wittenberg,
Institute of Geosciences and Geography,
Department of Sustainable Landscape Development,
Halle (Saale), Germany,
Email: janina.kleemann@geo.uni-halle.de

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Abbreviations

CICES	**Common International Classification of Ecosystem Services**
D	**Deliverable**
DSS	**Decision support systems**
DSS4ES	**Integrated DSS for delivery of ecosystem services based on EU forest policies**
ENFIN	**European National Forest Inventory Network**
EU	**European Union**
FAO	**Food and Agriculture Organization of the United Nations**
GIS	**Geographic Information System**
IPBES	**Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**
LiDAR	**Light Detection and Ranging**
MoU	**Memorandum of Understanding**
NCPs	**Nature´s Contributions to People**
NFI	**National Forest Inventory**
NGO	**Non-Governmental Organization**
NUTS	**Nomenclature of Territorial Units for Statistics**
WG	**Working Group**

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1. Summary of DSS4ES (partially taken from the memorandum of understanding - MoU)

Forests are a significant part of the surrounding landscape, and every management decision in the forest also affects the landscape, and vice versa. Management decisions in the surrounding landscape also affect the forests. Thus, a framework of integrated decision support systems (DSS) is needed to appropriately address all objectives of sustainable forest management in the landscape by linking all mutual relations between forests and the surrounding landscape. Such an integrated DSS framework will require the consideration of information and approaches from different rural and land-use activities and sectors. In this context, juxtaposition and integration of the knowledge from DSS (developed for farming, animal husbandry, forestry, ecosystem management, etc.) will be an excellent starting point for advancing toward an integrated system for sustainable assessing the provision of ecosystem service at landscape scale, including provision of resources for bio-based economic activities, protection and regulation, or cultural services. The main aim of this action is to establish a research network to facilitate the conceptualization and development of new methodological approaches in DSS, including important relationships between forests and landscapes. The emphasis is on screening, evaluating, and proposing existing and future tools to support holistic planning approaches to increase sustainable forest management, considering various ecosystem services and products addressing the associated risks and uncertainties.

2. Description of the Working Group (WG) 1 "Data and Knowledge"

The WG "Data and Knowledge" focuses on utilizing data sources, expert knowledge, empirical data, national forest inventories (NFIs), remote sensing data, and big data for quantifying ecosystem services as an important input for model-driven or data-driven DSS. The work will result in reports on data types, data sources, data quality, verification and validation of data, and knowledge to assist the overall system design of DSS, quality control, integration, sharing, and use in the planning process. It will deal with the data structure and architecture to build a spatial database system. It will address innovative approaches for data extraction from forest inventory/NFI, the use of monitoring systems such as remote sensing, as well as traditional knowledge sources (e.g., project results and scientific publications). Therefore, this task defines and documents data resources necessary for other working groups. This description has been taken from the DSS4ES MoU.

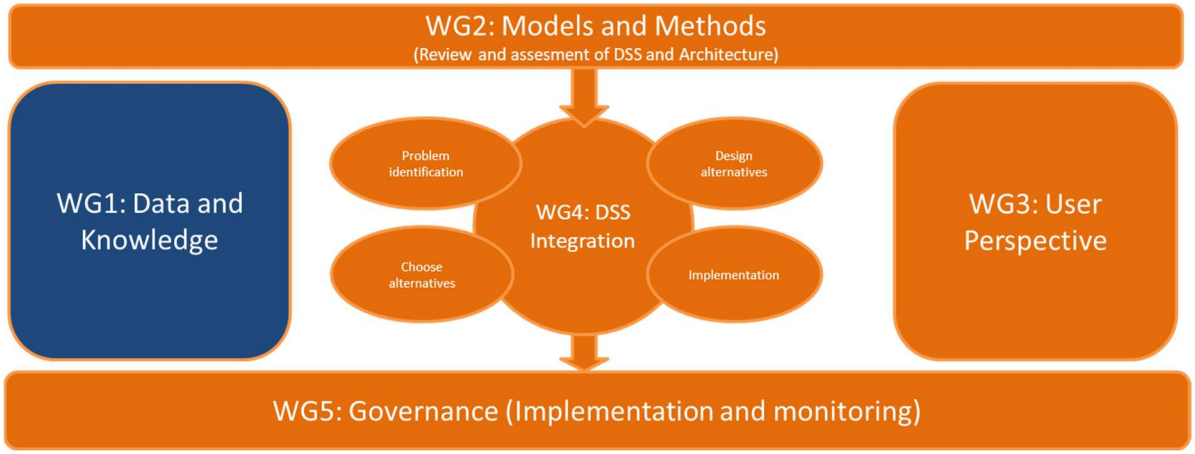

Figure 1: *The blue colour shows the Working Group (WG) 1 "Data and Knowledge" in the WG framework of DSS4ES.*

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WG1 has just recently started to consolidate the tasks and related responsibilities to accomplish the defined objectives. The Email list was created on 26th June 2024. WG1 has 97 members from 25 European countries – and one member from Morocco and Jordan, respectively (status of July 2024, when this task was started). Of the total WG1 members, 75 members are from Inclusiveness Target Countries (~ 77%), 48 are young researchers (~ 49%), and 29 are female members (~ 30%). The share of female WG1 members could therefore be improved.

3. Description of the Deliverable (D) 1.1

The task related to the first deliverable in WG1 was to investigate existing EU-wide digital (especially spatial) technologies for forest / landscape inventorying and monitoring, with special emphasis to those data and datasets that can be used or are already used in combination with DSS to support natural resources management in the context of forestry. In order to feasibly fulfil the task in a given time frame, we have started to collect information of spatial data related to forests on the EU level, as well as country-specific data on the national level per WG1 member country. Section 4 describes the data collection process.

Please note that it is not the primary aim of this deliverable (and also not the aim of WG 1) to technically harmonize all available forest-related data on the national level because there is already a European initiative to harmonize National Forest Inventories – the European National Forest Inventory Network (ENFIN). EINFIN is a platform to improve the data comparability of forest information across European countries. ENFIN suggests a large-scale monitoring system at the European scale (ENFIN 2024). Of the 27 EU member countries, 23 have a National Forest Inventory (NFI; ENFIN 2021). Scientifically published attempts at harmonization are, e.g., related to stem volume (Gschwantner et al., 2019) and stock growth (Gschwantner et al., 2022) – therefore, wood/timber production as the most relevant provisioning ecosystem services – but also related to biodiversity information of main forest types and tree species groups (Gschwantner et al., 2024). We will enrich this overview of forest-related information by adding data on more ecosystem services. In addition, ENFIN focuses on national forest inventories, but we also try to explore other national spatial data sources.

4. Process of data collection and selection

We followed a step-wise approach to finally create a common data categorization. In our first DSS4ES meeting, conducted online on 6 March 2024, links to databases in the context of DSS4ES provided by meeting participants were collected in Miro Board (Annex 1), an interactive online tool. In total, 42 sticky notes with comments and links were provided. The WG 1 leader conducted a preliminary sorting into categories, e.g., product name, frequency, resolution of data, in an Excel table. The preliminary sorting of categories was presented and discussed in the DSS4ES meeting in Prague on 13 June 2024. All meeting participants were divided into four groups and worked on specific but different cases of DSS in the context of forest and ecosystem services. The feedback was collected, and the list of categories was adapted. The final list of categories is shown in Table 1. On 11 July 2024, the template with the categories and the guideline (Annex 2) on how to fill the country-specific report of available / accessible forest-related spatial data on a national level was sent to the WG1 members. The deadline for country report submissions was 10 September 2024. For new members, there has been an

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extension of the deadline to 10 October, and there was also time to improve the submitted reports after the hybrid meeting on 12 September 2024 in Zurich.

Table 1: *Overview of finally selected categories to describe the metadata for the data sets and their definitions.*

Category	Definition
Data name	Common name of data (or short version) according to the website, e.g. Copernicus Land Monitoring Service
Institution	It is the institution which creates /provides the data, e.g., Copernicus
Product	E.g., Global Forest Map
Description	Short and precise description of the data
Product type or data type	E.g., raster-classified, continuous, vector data
Spatial coverage	Primarily on a national level (if not available, second, on a province or district level)
Spatial resolution or scale	E.g., 25m, 100 m, points every 2 km etc.
Frequency of data acquisition	E.g., annually, periodically
Years	For which years data are available, e.g., 2015, 2023
Sensor or database	E.g., sensor: TanDEM-X, Sentinel -2; database: Land Cover Characteristics database (GLCC) from AVHRR
Description / classes of land use / forest	E.g., classes: canopy cover > 90%, canopy cover 10-90%; forest cover, tree density; closed forest, open forest, woodland
Used land use / forest definition	Please enter here the underlying land use / forest definition of the data / product, e.g. FAO forest definition
Suitable for which ecosystem services to be assessed	You can enter the ecosystem services for which the specific data can be potentially used (for an ecosystem services analysis) or is already used, e.g., biomass, recreation, water infiltration
Producer accuracy of data (%)	The map accuracy from the point of view of the map maker (the producer), e.g., 72% - 89%
Access to data	Restricted (by registration only, by payment only), no access, open access
Link / Reference to the data	Link to the Website/download
Comment	Any comment you want to make related to data in the specific row

5. Overview of spatial data on EU- and global level

Spatial forest-related data on EU and global levels based on remote sensing have been collected in addition to national data to get an overview of comparable information for DSS at different levels. Remote sensing data are often available in shorter temporal frequencies than national forest inventories/field data collections but often have a lower spatial resolution (ENFIN, 2021).

The collection of data on forests on global and European levels has proved fruitful, and the search has not yet exhausted all available datasets. So far, 47 datasets have been collected, with mainly forest datasets and a preliminary search for databases on soil and climate data (Table 2). The complete list with website links is provided in Annex 3. Criteria for this list were:

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1) spatial data (excluding statistical data, e.g., providing figures for countries in the form of a table),
2) forest- and/or forest-ecosystem-services-related data, and
3) with spatial extension to the EU.
Due to the large selection of datasets with global and European extent, national datasets were largely ignored in this collection but included in the national country reports (Section 6).

Of the 47 datasets, 18 datasets were on the EU level (the remaining on the global level). On the EU- and global levels, mainly raster data were found with the most common spatial resolution of 30 meters, but ranging from 10 meters up to 25 kilometers. Thematically, most of the datasets listed represent forest/tree cover density. In addition, there are data available on forest extent, greenhouse gas flux, classified forest loss, wildfires, canopy height, biomass, forest habitat pattern characterization, forest productivity, forest types, and leaf types. Many datasets have been listed in data catalogues and collections. Therefore, some datasets are closely related because they are based on the same source material or methods and represent similar topics.

Numerous land cover data are suitable for monitoring or assessing various ecosystem services (Table 2). Regarding ecosystem services, the currently collected datasets are mainly suitable for provisioning (timber/biomass provision, habitat provision) and regulating ecosystem services (carbon sequestration) due to the focus of data on carbon (NPP, biomass, etc.). Currently, 13 datasets (approx. 27%) are suitable for (broadly speaking) biodiversity analyses. However, the resolution is partially insufficient to make precise statements about biodiversity. The same applies, e.g., to the ecosystem service pollination. Fewer data have been available on cultural ecosystem services, which could be related to cultural values being difficult to quantify (Jones et al., 2022) and often have multidimensional aspects that could require more time and financial resources to assess their importance and value.

Table 2: *Overview of the collected datasets on EU- and global levels potentially for ecosystem services analyses. NOTE: The Classification is based on CICES V5.2 (Common International Classification of Ecosystem Services; Haines-Young and Potschin, 2010) and the definition of Nature's Contributions to People by Díaz et al. (2015, 2018).*

Ecosystem Services Section	Ecosystem Service	CICES V5.1 Equivalent	Proxy Indicator / Data	Allocation (ID) of the data set according to the ID in Annex 2
Provision	Biomass (Energy, Food, Material)	1.1.X.X	Tree Cover Density	2,9,33,36
			Diameter at Breast-height	23
			Net Primary Productivity	22
			Forest Cover	9, 10,30,36,46
			Canopy height	1
			Forest Restoration Potential	38,42,43
			Above Ground Biomass	7,17,44
			Land Cover	5,6,12,14,27,28,29
			Wood Production	25
	Water (drinking, hydropower)	4.1.X.X	Land Cover	5,6,12,14,27,28,29
			Land Cover Change	12,14, 31
	Habitat	2.2.2.3	Land Cover	5,6,12,14,27,28,29
			Tree Cover Density	2,9,30, 33,36

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			Forest Cover (loss)	9,10,36,46
			Forest Restoration Potential	38,42,43
			Canopy height	1
			Tree Cover loss	13,32
			ForestClim	24
			Vertical Vegetation Profile	11
			Forest Type/ Leaf Type	3,4
			Human pressure	40,45
			Landscape Metrics (e.g., connectivity, fragmentation)	19,21
Regulation	Pest and Disease	2.2.3.X	Tree Cover Loss	13,32
			Forest Condition	39,47
			Land Cover Change	12,14, 31
	Extreme events (Erosion, Flood, Fire, Urban heat island)	2.2.1.X	Tree Cover Loss	13,15,20,32,34,35
			Landscape Metrics (e.g., connectivity, fragmentation)	19,21
			Land Cover change	10,12,14, 31
			Vertical Vegetation Profile	11
			Wildfires	15,20,35
			Tree species	8
			Urban tree cover	26
			Forest Condition	39,47
			Climate Data	24
	Pollination & seed dispersal	2.2.2.X	Vertical Vegetation Profile	11
			Tree species	8
			Land Cover	5,6,12,14,27,28,29
	Climate (Carbon seq.) and air quality	2.2.6.X	Climate Data	24
			Net Primary Productivity	22
			Forest Restoration Potential	38,42,43
			Potential Forest Cover	37,41
			Above Ground Biomass	7,17,44
			Greenhouse Gases	16,18
	Biodiversity (genetic material)	1.2.X.X	Forest Type/ Leaf Type	3,4
			Vertical Vegetation Profile	11
			Human pressure	40,45
			Land cover	5,6,12,14,27,28,29
			Species/ Leaf type	4,8
	Soil formation	2.2.4.X	Human pressure	40,45
			Land Cover	5,6,12,14,27,28,29
			ForestClim	24
Cultural	Outdoor activities	3.1.X.X	Tree Cover loss	10,13,32
	Symbolic values	3.2.X.X	Biodiversity (e.g., tree species)	8

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6. Overview of spatial data on the national level per country

Of the 25 European countries´ representatives in WG1, reports of 18 countries (72 % of the WG1 member countries) were submitted. In total, 232 items of dataset information were submitted. All country reports are shown in Annex 5. The spatial coverage across Europe is balanced (Figure 2). The highest number of collected datasets was provided by Serbia, with 33 datasets presenting national and provincial levels. The highest number of datasets on the national level was provided by Turkey with 29 datasets (Figure 3). On the other hand, only 7 datasets of those provided by Turkey were freely accessible (Figure 4) – at least where open access was clearly mentioned. Similarly, for Serbia where only 2 of the 33 datasets might be open access. In many cases, the type of permission needs to be figured out when actually accessing the data. The highest amount of open-access data was provided by Germany, with 20 datasets, followed by Austria (19) and Poland (17). The dataset types per country were mainly available as vector data (Figures 5 and 6), while on EU- and global level, mainly raster data were found (see Annex 2). No vector data were identified in the provided dataset for Albania and Czechia. In addition to vector and raster data, spatial point data, statistical data and text data were submitted. The spatial resolution of the vector data was up to 1:250,000 (the maximum among all countries). The raster data varied between 1 to 1000 meters (Table 3). The range of years of data collection was updated to 2024 in 10 countries (40% of the WG1 member countries). The oldest dataset was provided by Slovakia from the year 1764 for a text document of the Forest Management Plan (Table 3). The type of forest definition used is not clear among and within the countries and varies per dataset (Figure 7), even though the forest definition according to the FAO Forest Resources Assessment (FAO 2018) was used most often. This fact also has consequences for recording spatial coverage of the land use type “forest”. Furthermore, there could have been gaps in understanding and knowledge about forest definitions used in the datasets while filling the table of the country report by the WG1 members. The number of potentially measurable ecosystem services was highest for regulating ecosystem services, especially for Serbia and Germany (Figure 8). For example, carbon sequestration, climate regulation, soil conservation, and water regulation were mentioned here. Timber production was, of course, the most often mentioned provisioning ecosystem service. Similar to the datasets on the EU level, cultural ecosystem services were less often mentioned – however, at least in 8 countries (32% of the WG1 member countries). Other potential topics were mentioned concerning ecosystem services but not sorted into CICES categories, e.g., ecosystem resilience, sustainable management, regeneration, and conservation. A new emerging ecosystem services concept and, therefore, also a new classification system is the concept of Nature´s Contributions to People (NCPs; Díaz et al. 2015, 2018). NCPs are similar to ecosystem services but follow the classification of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Due to this trend, we also analyzed the ecosystem services provided by the countries according to NCPs. Here, mainly ecosystem services provided by Portugal, Germany, and Serbia could also be measured with the NCP concept.

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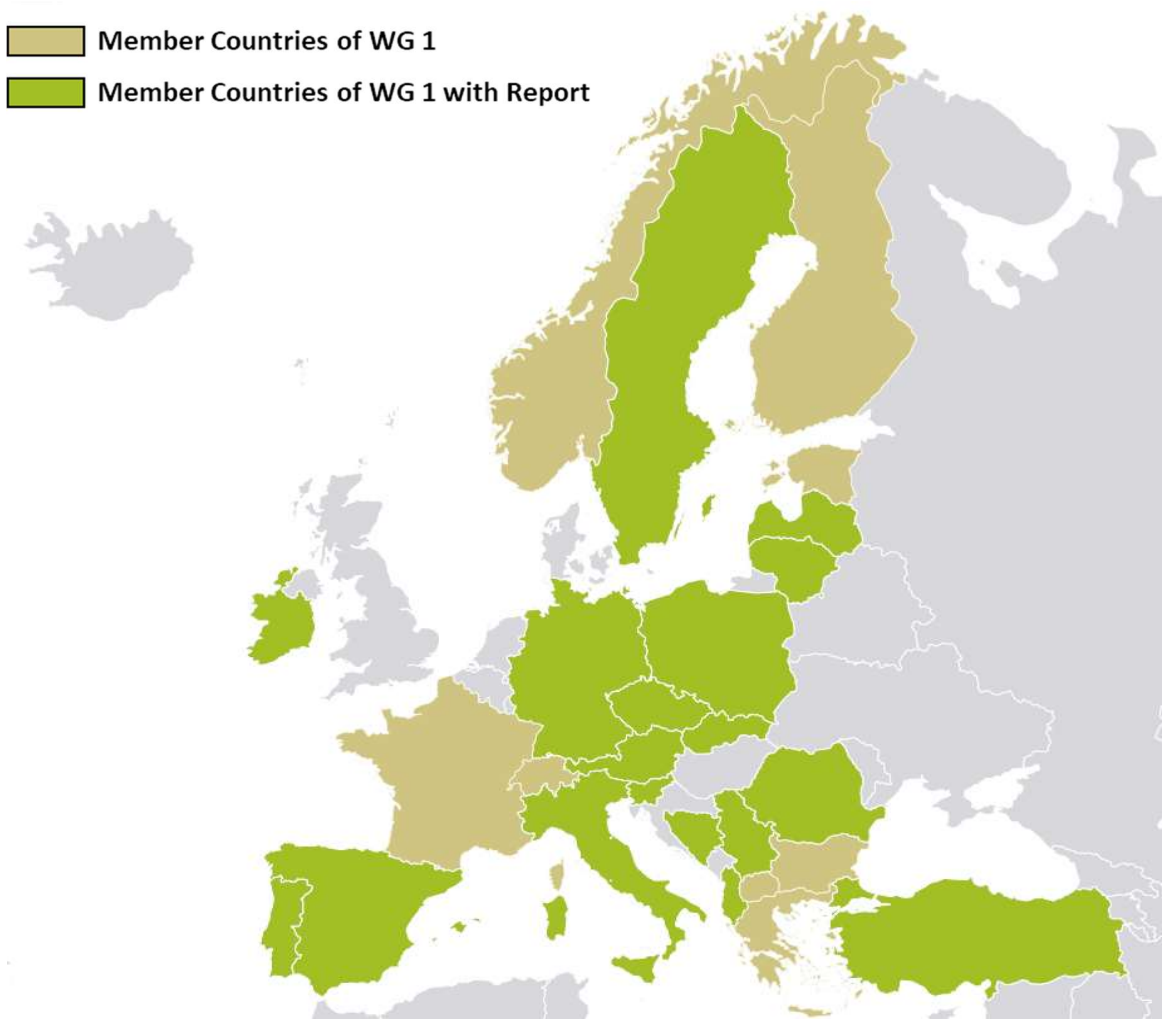

Figure 2: *Member countries of working group (WG) 1 (brown) and member countries of WG 1 who submitted a country report (green). All country reports are provided in Annex 5.*

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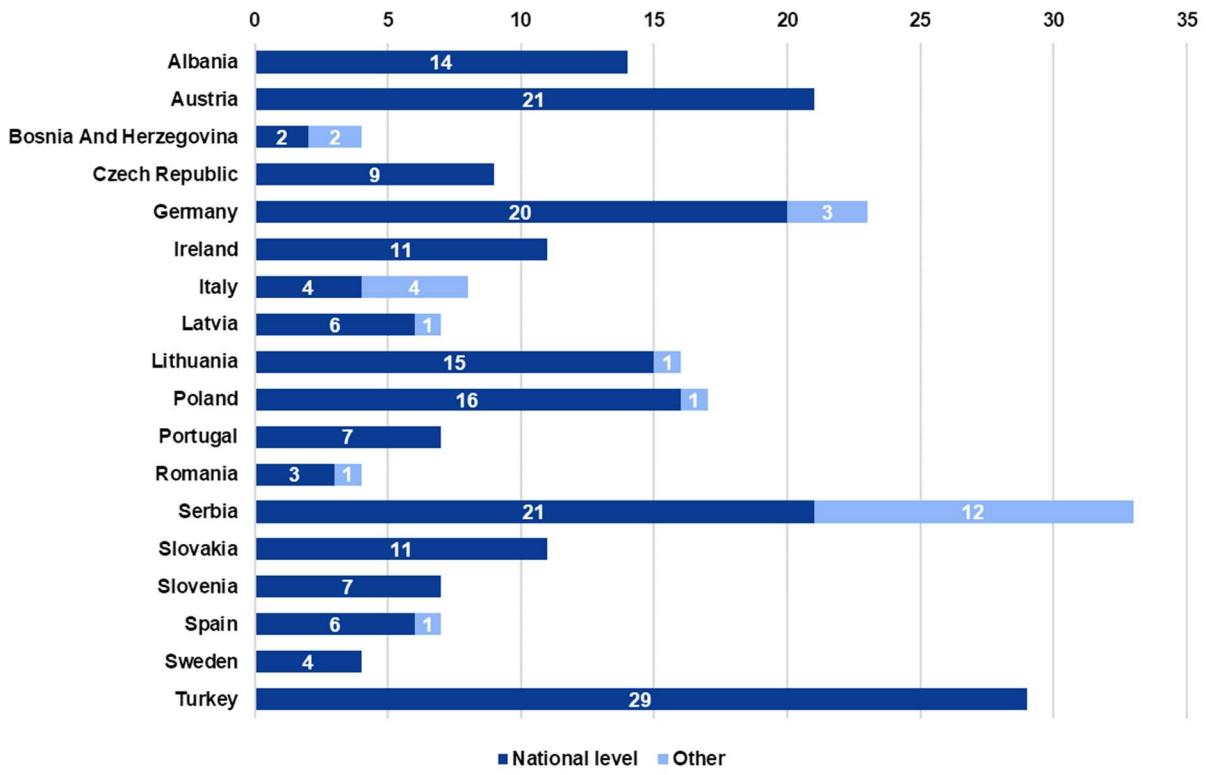

Figure 3: *Datasets collected on national and other levels within the respective country. The countries are alphabetically sorted.*

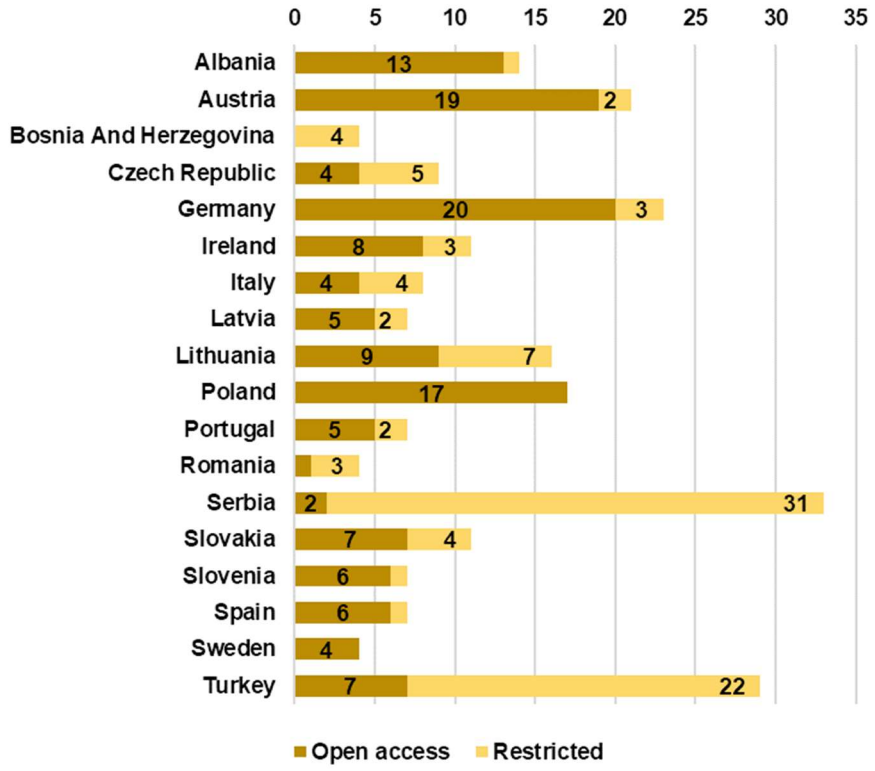

Figure 4: *Number of open access data per country. The countries are alphabetically sorted. Please take a look at Annex 4 for an overview of other terminologies used and the finally chosen generic terms. The total number of open access data: 118.*

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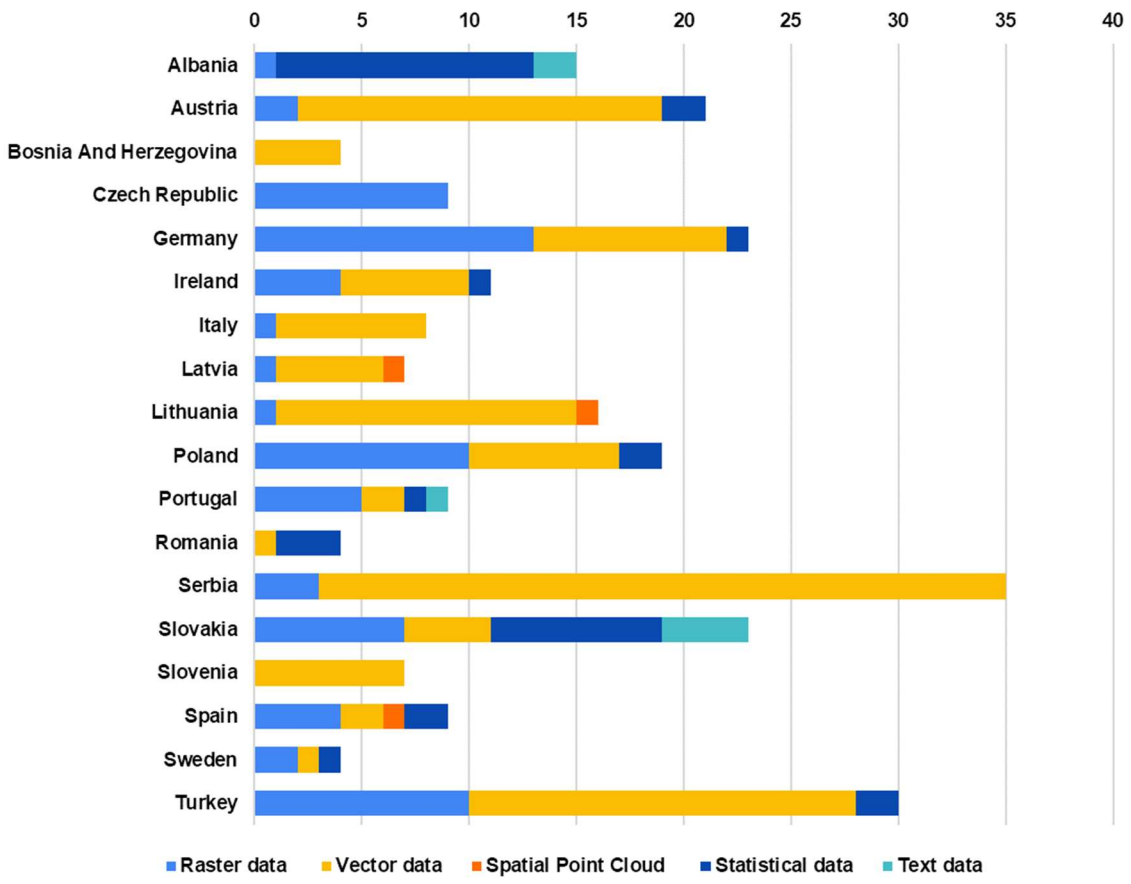

Figure 5: *Dataset types per country. The countries are alphabetically sorted. Please look at Annex 4 for an overview of the other terminologies used and the finally chosen generic terms.*

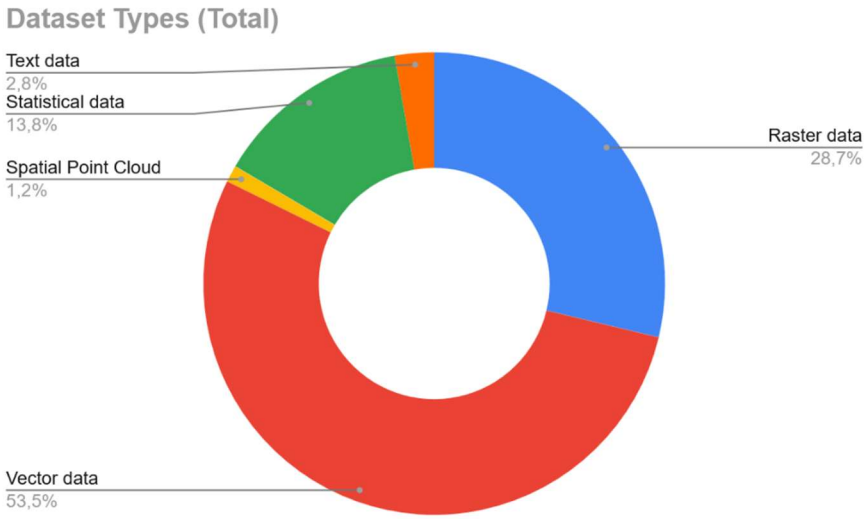

Figure 6: *Dataset types in total. Please look at Annex 4 for an overview of the other terminologies used and the finally chosen generic terms.*

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Table 3: *Overview of the ranges of the years of data collection, the spatial resolution of the raster data or scale of vector data and the frequency of data collection per country. The countries are alphabetically sorted. Please look at Annex 4 for an overview of the other terminologies used and the finally chosen generic terms.*

Country	Years of data collection		Spatial resolution (Raster) [m]		Spatial resolution (Vector) [scale 1: x]		Frequency of data collection	
	Earliest	Latest	Highest	Lowest	Highest	Lowest	Shortest	Longest
Albania	1998	2023	-	-	-	-	Annually	Decadal
Austria	1987	2024	-	-	10	50000	Daily	Decadal
Bosnia and Herzegovina	1960	2009	-	-	25000	200000	Decadal	Decadal
Czech Republic	1999	2023	500	500	-	-	Annually	Every 12 years
Germany	1987	2024	1	100	10000	200000	Monthly	Decadal
Ireland	2006	2022	50	50	1000	250000	Every 5 years	Every 5 years
Italy	2009	2023	10	10	1000	25000	N/A	N/A
Latvia	1991	2024	10	10	2000	10000	Every 6 years	Annually
Lithuania	1950	2023	-	-	5000	50000	Decadal	Decadal
Poland	1978	2024	1	100	-	-	Annually	Every 30 years
Portugal	1980	2023	10	250	-	-	Daily	Decadal
Romania	2008	2024	-	-	50000	50000	Every 5 years	Decadal
Serbia	1950	2024	10	1000	1000	50000	Daily	Decadal
Slovakia	1764	2023	15	15	-	-	Monthly	Decadal
Slovenia	1970	2024	-	-	2000	25000	Annually	Annually
Spain	2008	2024	20	20	25000	25000	Every 8 years	Decadal
Sweden	1923	2024	10	10	-	-	Daily	Annually
Turkey	1963	2024	5	100	20000	25000	Every 2 days	Decadal

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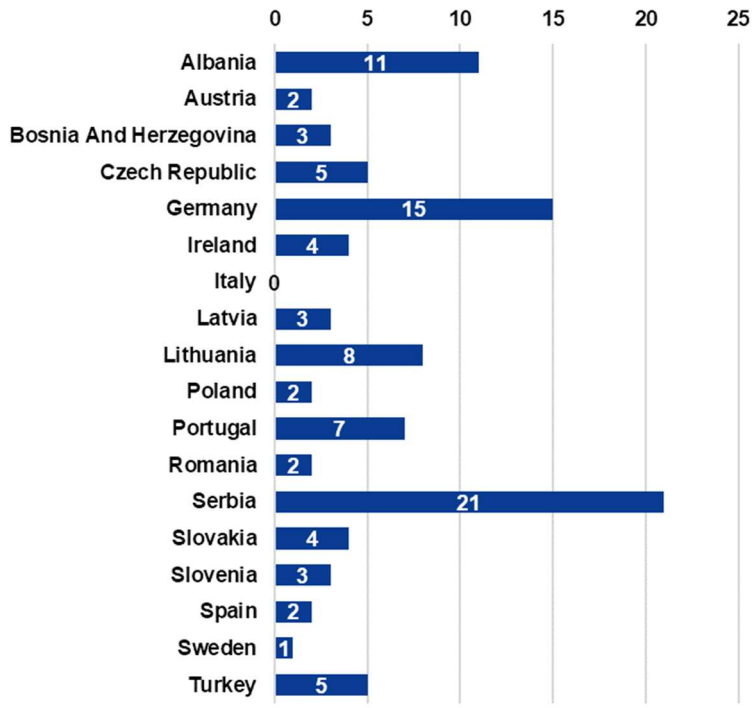

Figure 7: *Amount of forest definitions used / provided per country. The countries are alphabetically sorted.*

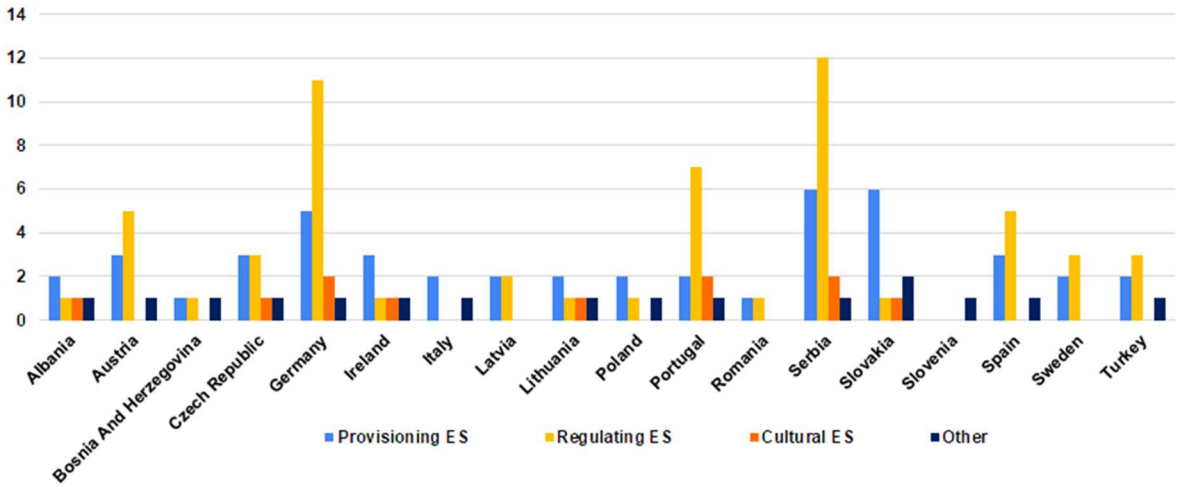

Figure 8: *Number of potentially measurable Ecosystem Services (ES). The Ecosystem Services Classification is based on CICES V5.2 (The Common International Classification of Ecosystem Goods and Services; Haines-Young and Potschin, 2010). Providing CICES codes for Slovenia were not possible because the ecosystem services were described too generally or not at all. The countries are alphabetically sorted. Other = Ecosystem resilience, sustainable management, land use planning, growth form, regeneration, conservation and protective forests.*

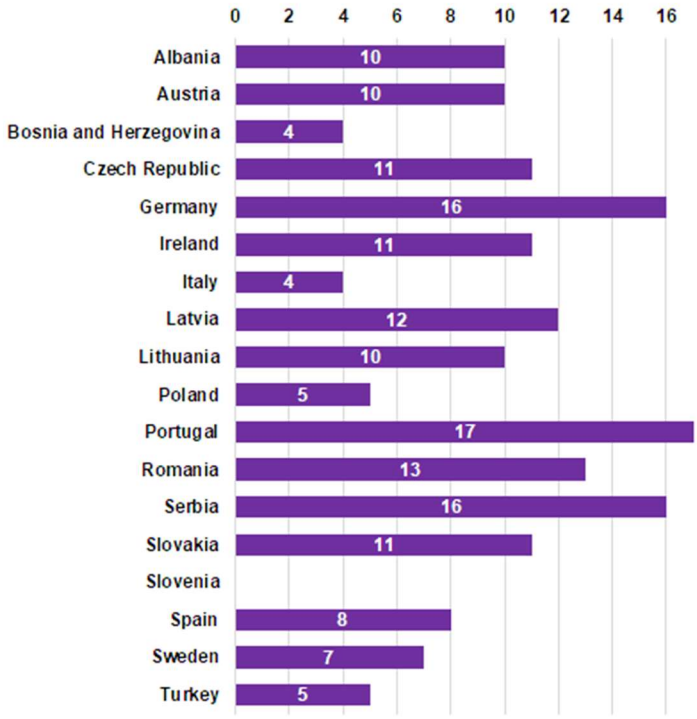

Figure 9: *Number of potentially measurable Nature´s Contributions to People (NCPs; Díaz et al. 2015, 2018). NCPs are similar to ecosystem services but follow the classification of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). There exist 17 classes of NCPs. Providing NCPs for Slovenia were not possible because they were described too generally or not at all. The countries are alphabetically sorted.*

7. Discussion of the findings and data / knowledge gaps

At the EU level, it is known that national forest inventories vary between countries by forest definition, data gathering methods, years, and resolution. Our data collection also confirms this finding (e.g., see Figure 7). Regarding data collection methods, the methods of analyzing forest area and usable biomass for wood supply differ between countries (Alberdi et al., 2020). There are attempts to harmonize forest data on the EU level, e.g., see Alberdi et al. (2020), Gschwantner et al. (2022), and Avitabile et al. (2024). However, in these "harmonization processes", information gets lost on the EU level due to the attempt to find the least common denominator. For example, European NFIs use different threshold values for tree volume estimation, and during harmonization efforts diameter thresholds had to be agreed upon, despite some countries using smaller or no thresholds for certain tree parts (Gschwantner et al., 2019). Additionally, Avitabile et al. (2024) report that smaller-scale geographic units were harmonized into the Nomenclature of Territorial Units for Statistics (NUTS) classification system.

Even though in this report we focused on a national level, we could identify a few common data gaps and knowledge gaps among the countries. For some countries, e.g., Serbia, Albania, Bosnia and Herzegovina, **data accessibility** is the most limiting factor of forest- and DSS-related information. In addition, **data quality and its assessment** are lacking for some countries even though this was not the case for Slovakia and Germany, among others. An orientation for data quality is, among others, information about data accuracy, producer accuracy, and other accuracy / uncertainty analyses. However, for many datasets on a national level, no information about the accuracy has been provided

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– compared to the EU-wide datasets. And no data accuracy can be detected for locally collected data, i.e., field data. In the case of Romania and Latvia, the main important aspect is **data reliability**. For example, Romania has no centralized mechanism for data storage and exchange at the national level. Various types of data are collected in Romania by multiple institutions, e.g., the National Institute of Statistics provides a certain type of data coming from official reports, but the NFI provides a systematic type of data that covers all of Romania, which is considered as forest. To this matter, various national and international bodies do not know what source is reliable, so they tend to either make a mean value or choose whatever fits best (e.g., Eurostat uses NFI, but in various research articles or reports, data from National Institute of Statistics are preferred).

In addition, forest inventory data may **not be updated regularly** due to personnel or financial constraints or a different policy focus. For some countries, e.g., Italy, Ireland, and Turkey, a major problem is the **inconsistency and irregularity of data updates, which complicates regular monitoring**. As in the case of Italy, data updates are typically project-dependent and not conducted regularly. This makes it challenging to carry out detailed spatio-temporal analyses, especially for long-term studies or studies requiring continuous data over time. These gaps are particularly evident in the specialized data from the NFI and Forest Carbon Pools of Italy, where the mapping is incomplete and often requires direct and local contact with data.

Data is often lacking about **biodiversity** (whether it is habitat diversity or species diversity), e.g., in the case of Bosnia and Herzegovina but also for Germany, among others. For example, for Germany, Portugal, and Poland, the spatial resolution is not yet resolved enough to make precise statements about biodiversity or pollination. Or data are spatially scattered. Furthermore, as in the case of Bosnia and Herzegovina, spatial data about non-forested areas eligible or suitable for reforestation is missing.

As for **ecosystem services**, it was interesting to see that many different regulating ecosystem services can be potentially identified by our collected country datasets (Figure 8), even though this finding does not mean that regulating ecosystem services are easy to measure or monitor. In general, the complexity of quantifying different ecosystem functions and services requires larger datasets, considering overlaps between the various sectors. The lack of a common data-sharing policy between most institutions and sectors complicates data exchange and use.

In general, **cultural ecosystem services** can be investigated less with the currently collected national and international data than provisioning and regulating ecosystem services. However, according to the EU Commission[1], key forest ecosystem services that are presently under pressure are biomass provision (wood and non-wood), carbon sequestration, habitat for biodiversity, water filtering and cycling, soil protection, and nutrient cycling, which are also provisioning and regulating ecosystem services and not cultural ecosystem services. Even though land productivity may be easier to assess than cultural ecosystem services, data for local productivity might be assessed only on the dominant tree cover and not explicitly based on soil or geological characteristics (as exemplified for Turkey). In general (not only related to cultural ecosystem services), data collection efforts for forest management may **lack engagement with local communities** and stakeholders. This can result in gaps in understanding local ecological knowledge and the socio-economic factors influencing land use

[1] Presentation by Adrián Tišťan, Land Use and Management Unit, European Commission, 8th Feb. 2024, COST Connect Meeting in Brussels.

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decisions and assessing ecosystem services. The EU-funded project "Distributed, Integrated and Harmonized Forest Information for Bioeconomy Outlooks" (DIABOLO) surveyed social and recreational data in European NFIs. While 31 out of 35 countries answered their questionnaire, they used some sort of specific social or recreational variable or a variable relevant to social and recreational use. Almost all participating countries did not integrate the data into reporting or secondary analysis because the collected social data was only recently added to the inventory, except Switzerland. Only a few European countries collected detailed information about the social and recreational use of forests or other variables relevant to this topic (Atkinson et al., 2020).

In this context, indicators are often understood as proxies for estimating ecosystem services as they capture some physical elements of ecosystems that can be relatively easily quantified with available methods and tools to monitor and assess the provision of those services. Many European countries use different sets of indicators to estimate the quality and quantity of ecosystem services at a national level. However, in a recent literature review of indicators to measure ecosystem services according to the CICES (v5.1) classification system, it was analyzed which of the 85 indicators could be derived from remotely sensed (RS) data (Grima et al., 2023). Only a minority of the indicators (6) could be directly derived from RS data. In contrast, most indicators (46) could be derived indirectly by using additional information or modelling, and 33 indicators were not derivable from RS data. Therefore, it can be assumed that the purpose of the indicator strongly influences the potential of an indicator to be derived from RS data and whether it is meant to represent the relevant structure, function, service, benefit, or value of an ecosystem service. So, even when the data and information are available on a national level, linking them to an appropriate indicator set that can be used for decision support systems is still challenging.

8. Recommendations

Data accessibility and quality for forest- and ecosystem services-related DSS need to be improved in most of the countries. The challenge is, for instance, developing applications for automatized stand mapping, improving the methodology for mapping forest ecosystem services and related functions, integrating remote sensing techniques to improve data quality and increase control of forests and forest management. Efforts to harmonize methods and data needs, would allow a more cost-effective implementation throughout all member countries and getting more control on the challenges related to data diversity and quality (Camaretta et al., 2020). In most countries, a transition to more digital elements (e.g., digital callipers, digital vertexes, drones, and smartphones with LiDAR and augmented reality) and office equipment (e.g., powerful computers, servers, and software) should be implemented in combination with an upgraded spatial information system to provide support for the most demanding spatial analyses, planning, and implementation of forest management with the main task of simplification, optimization, and upgrade (Gollob et al., 2021; Torresan et al., 2017). For forest owners and other stakeholders, this will lead to a more efficient and streamlined service, enhanced by increased data availability, reduced bureaucracy, and quicker, clearer access to information regarding forest and forest management. Installing new applications will provide forest owners and managers with enhanced insights into the history of forest development and management, along with tools that facilitate participatory decision-making.

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Biodiversity information is more often collected for protected forest areas, while data collected outside protected areas tend to focus more on forest cover and timber production, with insufficient attention given to biodiversity conservation (even though some traditional forest attributes can be used for that purpose) and the social dimensions of ecosystem services. **Integrating more diverse indicators,** such as community well-being and cultural values, would provide a more holistic view of ecosystem service dynamics (Torralba et al., 2020). Detailed **national assessments should be conducted or improved that quantify various ecosystem services** provided by forests, e.g., carbon sequestration, biodiversity, and recreational value. This could involve establishing a standardized framework for measuring these services across different forest types, enabling more robust comparisons and evaluations. Remote sensing and GIS technologies should be used to gather more precise data on forest health, biomass, and changes over time. However, identifying synergies between the different data sources and their interoperability might be challenging (Grima et al., 2023).

Develop a **systematic approach on the national level to monitor and evaluate the effectiveness of forest-related management for different ecosystem services**. This could include establishing performance indicators and regular reporting mechanisms that provide feedback on policy outcomes at local levels. Foster collaboration among stakeholders, including government agencies, local communities, and non-governmental organizations (NGOs), to ensure that the policies are effectively implemented and adapted to meet the needs of diverse forest users.

Establish and support initiatives for data collection that follow specific standards (described above) at local and regional levels to inform the national level, allowing for a more nuanced understanding of forest conditions and management practices. Local inventories and community-based monitoring programs can help to capture variations that national data may overlook. Provide training and resources to local stakeholders and organizations on data collection methodologies (e.g., citizen science) and on communicating the importance of local assessments. This will empower communities to contribute to data gathering and improve local forest management practices (Tiebel et al., 2021; Piras et al., 2021). Although citizen science may not be a valuable strategy for every research and sometimes lacks correct data format and data quality, it can be beneficial as it possibly improves the acceptance of implementing the scientific outcome, integrating society in research and giving participants a chance to contribute and learn (Pettibone et al., 2016). Handbooks and guidelines exist that support the decision whether to use citizen science in specific cases and help to integrate citizen science into research (Pocock et al., 2014; Pettibone et al., 2016). For forest-related research, citizen science has already shown successful implementation cases that guide forest management decisions (Mair et al., 2016; de Groot et al., 2023).

Finally, establishing a **centralized online portal** – at least at the national level as a data unit – where all spatial data can be easily accessed and downloaded will facilitate broader usage by researchers, policymakers, and stakeholders. Following data collection standards, data should be regularly updated. In addition, expanding the database to include socio-economic data, information about land use change, and community-based forestry information will enrich the analysis of ecosystem services. Current national online portals often include forest data only as a subtopic – as in the cases of, for example, Austria, Ireland, Slovenia, Czechia, and Estonia, with only a few forest-related datasets. And in the case of Serbia, not all data in the centralized online portal is downloadable. In Germany, forest

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data is structured according to federal states ("Bundesländer"). Turkey provides open access to national forest statistics, and the most comprehensive portal can be found in Poland, which provides forest-related digital maps, statistics, and publications.

9. Next steps

The global and national data tables could be complemented by a column for which specific DSS models and respective collected data are suitable (collaboration with DSS4ES WG 2 and WG 4), but we need to figure out if this approach is feasible. We should focus more on those datasets that can be used or are already used in combination with DSS. Together with the other WGs, we will develop concepts for interfaces for linking new data sources to DSS. More country reports could enlarge data sets, and the currently submitted reports can be refined. A collection of local/regional level data per country and more project-related data could be added – if needed – to bring forward the process in DSS4ES. We will now focus more in-depth on the specific ecosystem services that can be analyzed and assessed by the different datasets and models. We will further explore the usage of the IPBES classification of NCPs instead of or in addition to the CICES classification for ecosystem services. Furthermore, we will collect information/data specifically on the Internet of Things and Big Data for landscape management in the context of DSS4ES. The Internet of Things enables the communication and exchange of data in real-time, e.g. Live cameras (such as EarthCam), streaming webcams of species and landscape monitoring that could be used for DSS. Other innovative approaches for data extraction from forest-related ecosystems could be screened in a literature review with a distinction between early-stage research prototypes and fully commercialized solutions and across different European countries. In addition, we will further exchange with the working groups of stakeholders (WG 3) and governance (WG 5) in order to link data with the needs of potential users, policymakers and managers. We will also be attentive to check further activities and outputs of ENFIN, forest-related EU projects, and COST Action projects.

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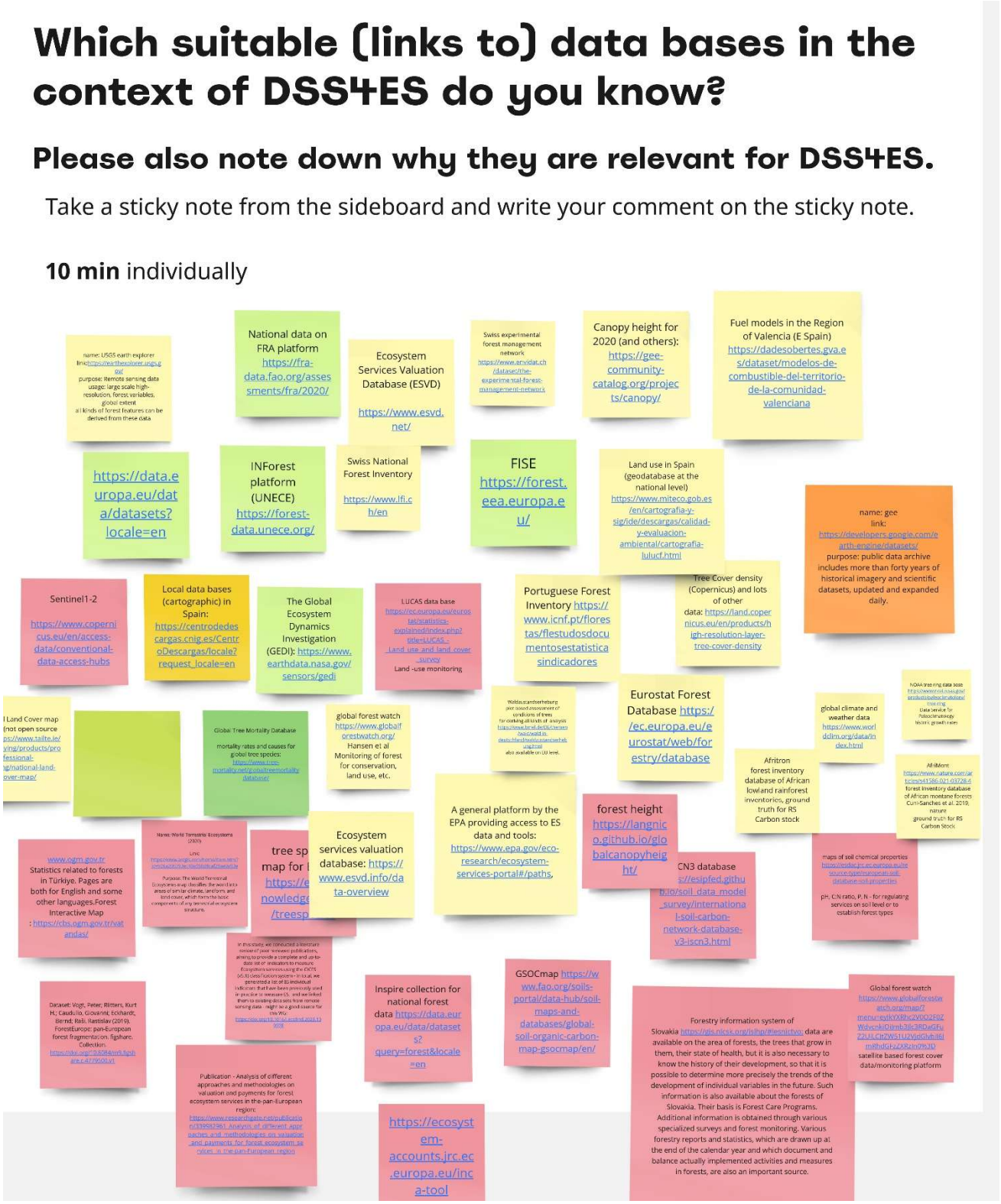
Annex 1: Collection of links in Miro board from the online meeting in March 2024



Annex 2: Table of spatial data on EU- and global level. Please zoom in to read the details.

Nr.	Data	Institution	Product	Description	Type	Spatial coverage	Spatial resolution or scale	Frequency	Years	Sensor	Description / classes	Used forest definition or similar terminologies	Suitable for which ecosystem services assessment	CICES V5.1 Equivalent	Accuracy	LINK	Access	General Comment
1	ETH Global Sentinel-2 10m Canopy Height (2020)	ETH Zürich	geotiff on Canopy Height	Combination of Sentinel-2 and GEDI data for a global canopy height raster with uncertainties	raster continous	Global	10m	once	2020	Sentinel-2	Canopy height, m, whole numbers	not specified	P:Biomass, Habitat	1.1.X.X, 2.2.2.3	standard deviation of values available as extra layer (0-15m)	https://gee-community-catalog.org/projects/canopy/	free https://www.research-collection.ethz.ch/handle/20.500.11850/609802	More info: https://arxiv.org/abs/2204.08322
2	European Tree Cover Density	Copernicus	Tree cover density raster	High resolution european tree cover density, 3-yearly	raster continous	Europe	10/20 and 100m	every 3 years	2012, 2015, 2018	Sentinel-2A, Landsat 8, SPOT-5 and ResourceSat-2 satellite	tree cover from 0-100%	Tree Cover Density: proportional crown coverage per pixel using the vertical projection of tree crowns to a horizontal earth's surface	P: Biomass, Habitat	1.1.X.X, 2.2.2.3	≥ 90%	https://land.copernicus.eu/en/products/high-resolution-layer-tree-cover-density	restricted (EU Login - free)	
3	European Forest Type	Copernicus	Forest type raster	European high resolution layer for forest type	raster classified	Europe	10/20 and 100m	every 3 years	2012, 2015, 2018	Sentinel-2A, Landsat 8, SPOT-5 and ResourceSat-2 satellite	all non-forest areas / broadleaved forest / coniferous forest (/ unclassifiable / outside area)	FAO, Link to FAO definition: https://www.fao.org/4/ad665e/ad665e06.htm	P: Habitat; R: Biodiversity,	2.2.2.3, 1.2.X.X	< 85%	https://land.copernicus.eu/en/products/high-resolution-layer-forest-type	restricted (EU Login - free)	
4	European Dominant Leaf Type	Copernicus	Dominant leaf type raster	European high resolution layer for dominant leaf type	raster classified	Europe	10/20 m	every 3 years	2012, 2015, 2018	Sentinel-2A, Landsat 8, SPOT-5 and ResourceSat-2 satellite	all non-tree covered areas / broadleaved trees / coniferous trees (/ unclassifiable / outside area)	covers the extend of the tree cover density layer https://land.copernicus.eu/en/products/high-resolution-layer-tree-cover-density	P: Habitat; R: Biodiversity,	2.2.2.3, 1.2.X.X	≥ 90% (overall accuracy 96.52%) https://land.copernicus.eu/en/technical-library/hrl-forest-2018/@@download/file	https://land.copernicus.eu/en/products/high-resolution-layer-dominant-leaf-type?tab=main	restricted (EU Login - free)	More info: https://land.copernicus.eu/en/technical-library/hrl-forest-2018/@@download/file
5	CORINE Land Cover	Copernicus	Land Cover	European Land Cover and Land Use inventory	raster and vector classified	Europe	25 ha / 100 m	every 6 years	1990, 2000, 2006 2012, 2018	1990: Landsat5; 2000: Landsat7; 2006: Spot4/5 & IRS P6 LISS; 2012: IRS P6 LISS & Rapideye; 2018: Sentinel2 & Landsat8	Corine Land Cover Nomeclature Guidelines	Corine Land Cover Nomeclature Guidelines. Under 3.1 Forest	P: Habitat, Water, Biomass; R: Pollination	1.1.X.X, 4.1.X.X, 2.2.2.3,2.2.2.1	≥ 85%	https://land.copernicus.eu/en/products/corine-land-cover	restricted (EU Login - free)	Is this absolutely or not at all relevant in this context?
6	Land Use/Cover Area frame Survey (LUCAS) - forest types	Copernicus	Point data on land cover and land use from field surveys	European land cover, land use, and environmental parameters for selected points	csv, point data	EU	Point level: LUCAS points belong to the intersections of a 2 x 2 km grid	every 3 years	2006, 2009, 2012 2015, 2018, 2022	Fieldwork	Eurostat Metadata on LUCAS. Classification under 3.2;	FAO, forest classification	P: Soil, Biodiversity; R: Climate, natural hazards, Water; C: urban and	2.2.4.X, 1.2.X.X,2.2.6.X ,2.2.1.X,3.1.X.X	field measurement, no accuracy assessment	https://ec.europa.eu/eurostat/web/lucas/overview	free	free data: survey on LU, LC, FAO parameter, land management, gully erosion, water management, landscape features, soil, photos
7	ESA Biomass Climate Change Initiative (Biomass_cci)	CEDA archive	Global raster datasets of forest above-ground biomass	raster data of above ground biomass and per-pixel, estimates of uncertainty	raster (geotiff and netcdf) continous	Global	100 m	irregular	2010, 2017, 2018 2019 and 2020	Sentinel-1, Envisat's ASAR instrument and ALOS-1 and ALOS-2	Mg/ha, whole numbers	Forest Above-ground Biomass: (live) dry mass per unit area	P: Biomass; R: Carbon	1.1.X.X, 2.2.6.X	Currently not specified, validation plan available	https://catalogue.ceda.ac.uk/uuid/af60720c1e404a9e9d2c145d2b2ead4e	free	Product Fact Sheet: https://admin.climate.esa.int/media/documents/CCI_Biomass_product_fact_sheet_V4.0_20230421_hk.pdf
8	Tree species maps for European forests	European Forest Institute	predictions of area for 20 tree species	set of 1x1 km tree species maps showing the distribution of 20 tree species over Europe	raster classified	Europe	1 km	once	2011	Fieldwork	See map legend https://efi.int/knowledge/maps/treespecies	dependent on EFI forest map https://efi.int/knowledge/maps/forest	R: Biodiversity, Extreme Events, Pollination	1.2.X.X, 2.2.1.X, 2.2.2.X	varies from tree species. estimated overall accuracy 43% https://link.springer.com/article/10.1007/s10342-011-0513-5	http://dataservices.efi.int/tree-species-map/register.php	restricted (EFI Login - free)	Publication: https://link.springer.com/article/10.1007/s10342-011-0513-5
9	Forest Map of Europe	European Forest Institute	european forest density map	map showing proportion of forest from land area for europe	raster, continous	Europe	1 km	once	2011	based on forest datasets optained from IRS, SPOT and NOAA-AVHRR	Forest % share of land area	Based on forest map by Kempeneers et al. 2011: forested land = tree crown cover (LC)	P: Habitat; R: Pest and Disease, Extreme Events; C: Recreation	2.2.2.3, 2.2.1.X,2.2.3.X ,3.1.X.X	not mentioned	https://efi.int/knowledge/maps/forest	restricted (EFI Login - free)	
10	Hansen Global Forest Change v1.11 (2000-2023)	Global Land Analysis and Discovery (GLAD)	Global high resolution raster data characterizing Global forest extent and change	30m resolution raster on canopy cover, global forest gain and loss from 2000 to 2012 and 2023	raster classified	Global	30 m	twice, around 10 years apart	period 2000-2012, period 2000-2023	Landsat	Tree canopy cover in percent, Global forest cover gain 2000-2012 as 1/0, year of gross forest cover loss event 0 (non) or 1-20 (corresponding to a year)	Tree cover: canopy closure for all vegetation taller than 5m in height; Forest gain: inverse of loss, or a non-forest to forest change entirely within the study period	P: Habitat; R: Extreme Events, Pest and Disease C: Recreation	2.2.2.3, 2.2.1.X, 2.2.3.X,3.1.X.X	> 90%	https://developers.google.com/earth-engine/datasets/catalog/UMD_hansen_Global_forest_change_2023_v1_11	free https://glad.earthengine.app/view/Global-forest-change#bl=off;old=off;dl=1;lon=20;lat=10;zoom=3;	Publication: https://www.science.org/doi/10.1126/science.1244693 More Information: https://storage.googleapis.com/earthenginepartners-hansen/GFC-2023-v1.11/download.html
11	GEDI L2B Canopy Cover and Vertical Profile Metrics Data Global Footprint Level	LP DAAC	Varied canopy and leaf cover indices resulting from laser ranging observations	High resolution laser ranging observations on Canopy Cover and Vertical Profile Metrics (Plant Area Index, Foliage Height Diversity, ...) 4.2 km across-track by one full ISS orbit along-track	HDF5	Global, but limited between 51.6°N and 51.6°S. Cut approximatly along London (GB) - Dortmund (D) - Łódź (PL)	25 m	varies	2019-03-25 to 2020-09-03	GEDI	canopy cover, Plant Area Index (PAI), Plant Area Volume Density (PAVD), and Foliage Height Diversity (FHD). https://lpdaac.usgs.gov/documents/588/GEDI_FCCVPM_ATBD_v1.0.pdf Algorithm Theoretical Basis Document for GEDI L2B Footprint Canopy Cover and Vertical Profile Metrics	https://lpdaac.usgs.gov/documents/588/GEDI_FCCVPM_ATBD_v1.0.pdf canopy cover: the percent of the ground covered by the vertical projection of canopy material LAI: one half of the total leaf area per unit ground surface PAI: like LAI + branches and trunks FHD: measures the complexity of canopy structure largely based on estimates of vertical LAI profile	P: Habitat; R: Biodiversity,, Extreme Events, Pollination , Biodiversity	2.2.2.3, 1.2.X.X, 2.2.1.X, 2.2.2.X,1.2.X.X	Included in dataset as layers	https://lpdaac.usgs.gov/products/gedi02_bv002/	free, but "Users cannot read the HDF5 files directly without using the HDF5 software library. Third party tools with HDF5 support include IDL and Matlab. The following list of open source tools is also applicable to GEDI HDF5 files: HDFView, Python" https://lpdaac.usgs.gov/data/get-started-data/collection-overview/missions/gedi-overview/	https://lpdaac.usgs.gov/documents/588/GEDI_FCCVPM_ATBD_v1.0.pdf
12	MEaSUREs GLanCE	LP DAAC	annual, Global land cover and change data	GeoTIFF raster offering yearly, global data on land cover, land cover changes and Enhanced Vegetation Index	raster	Global	30 m	annually	2001-2019	Landsat 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper Plus, and Landsat 8 Operational Land Imager	7: land cover class, estimated day of year of change, integer identifier for class in previous year, median and amplitude of the Enhanced Vegetation Index (EVI2) in the year, rate of change in EVI2, and the change in EVI2 median from previous year to current year	Boston University Website on Measure Glance Methods: https://sites.bu.edu/measures/project-overview/methods/ >30% Trees cover = forest	P: Biomass, Water, Habitat; R: Pollination, Biodiversity	1.1.X.X, 4.2.X.X, 2.2.2.3, 2.2.2.X, 1.2.X.X	Premliminary Accuracy: for North America 77.0 ± 2.0%. Tree cover within North America shows high User accuracy (83.9 ± 7.4%) frontiers article https://doi.org/10.3389/frsen.2022.894571	https://lpdaac.usgs.gov/products/glance30v001/	https://lpdaac.usgs.gov/products/glance30v001/#tools free	Frontier Publication: https://doi.org/10.3389/frsen.2022.894571 Boston University Website: https://sites.bu.edu/measures/
13	Tree Cover Loss by Dominant Driver 2023	Global Forest Watch	10 km grid cell assigning 5 dominant drivers to tree cover loss	GeoTIFF raster assigning 5 dominant drivers to global tree cover loss from 2001 - 2023	raster classified	Global	10 km	once	2001 - 2023	Landsat, MODIS	Commodity-driven deforestation, Shifting agriculture, Forestry, Wildfire, Urbanization	https://www.science.org/doi/10.1126/science.aau3445 defines dominant disturbance types	P: Habitat; R: Pest and Disease, Extreme Events	2.2.2.3, 2.2.3.X, 2.2.1.X	89%, with individual class accuracies ranging from 55% (urbanization) to 94% (commodity-driven deforestation)	https://www.arcgis.com/home/item.html?id=ff304784a9f04ac4a45a40f60bae5b26 https://data.Globalforestwatch.org/documents/ff304784a9f04ac4a45a40f60bae5	free	Science Publication: https://www.science.org/doi/10.1126/science.aau3445
14	Global Land Cover and Land Use Change, 2000-2020	Global Land Analysis and Discovery (GLAD)	Global land cover and land use change dataset	GeoTIFFs for land cover for 2000, 2005, 2010, 2015 and 2020, and 2000-2020 land cover/use change and explicitly forest height and extent changes	raster classified	Global	30 m	once	2000-2020	Landsat	under Dataset Details -> link to legend https://storage.googleapis.com/earthenginepartners-hansen/GLCLU2000-2020/v2/download.html	We defined forest as wildland, managed, and planted tree cover, including agroforestry and orchards. The forest height was mapped Globally for woody vegetation of ≥3m. https://glad.umd.edu/dataset/GLCLUC2020	P: Biomass, Water, R: Pest and Disease, Extreme Events, C: Recreation	1.1.X.X, 4.2.X.X, 2.2.3.X, 2.2.1.X, 3.1.X.X,	maps of forest extent 2000 and 2020 and the stable forest class extent both user's and producer's accuracies above 93%. The user's accuracy of forest gain (71%) [...] https://www.frontiersin.org/articles/10.3389/frsen.2022.856903/full	https://glad.umd.edu/dataset/GLCLUC2020	free https://storage.googleapis.com/earthenginepartners-hansen/GLCLU2000-2020/v2/download.html https://glad.geog.umd.edu/dataset/GLCLUC2020	Frontiers article: The Global 2000-2020 Land Cover and Land Use Change Dataset Derived From the Landsat Archive: First Results https://www.frontiersin.org/articles/10.3389/frsen.2022.856903/full
15	Global forest loss due to fire	GLAD	Global forest loss map divided into loss due to fire and other reasons	Hansen global forest loss map disaggregated into forest loss due to fire and other reasons	raster classified	Global	30 m	once	2001-2023	Landsat, SRTM, ASTER DEM	"disaggregated into forest loss due to fire vs. other disturbance drivers" https://glad.umd.edu/dataset/Fire_GFL/	Forest loss: the removal of woody vegetation exceeding 5 m in height. Forest loss due to fire: only the first stand-replacement forest disturbance between 2001 and 2019 was labeled as attributed to fire or non-fire for	P: Habitat; R: Pest and Disease, Extreme Events	2.2.2.3, 2.2.3.X, 2.2.1.X	Table 4 in forntier publication https://www.frontiersin.org/journals/remote-sensing/articles/10.3389/frsen.2022.825190/full#h4"The relative standard errors of the regional area estimates ranged from 4.0% to 12.3%"	https://glad.umd.edu/dataset/Fire_GFL/	free https://glad.umd.edu/users/Alexandra/Fire_GFL_data/2001-23/	Frontiers article: Global Trends of Forest Loss Due to Fire From 2001 to 2019 https://www.frontiersin.org/articles/10.3389/frsen.2022.825190/full
16	Forest greenhouse gas emissions	Global Forest Watch	Global forest greenhouse gas emissions from stand replacing disturbances	Modelled forest greenhouse gas emissions from stand-replacing forest disturbances	raster continous	Global	30 m	updated annually	2001-2023	Landsat, MODIS	1) megagrams of CO2 emissions/ha, and 2) megagrams of CO2 emissions/pixel	https://www.nature.com/articles/s41558-020-00976-6#Sec8 "Global maps of twenty-first century forest carbon fluxes" (Harris et al., 2021) > Methods > Forest definition and extend	R: climate (carbon seq.); C: UNESCO Heritage carbon sinks , forests managed by indigenous	2.2.6.X, 3.2.X.X	"Estimation of uncertainty is currently limited to the Global and biome scales based on available data for estimating uncertainty in the activity data." https://www.nature.com/articles/s41558-020-00976-6#code-availability	https://beta-gfw.opendata.arcgis.com/datasets/gfw::forest-greenhouse-gas-emissions/about	free https://beta-gfw.opendata.arcgis.com/datasets/gfw::forest-greenhouse-gas-emissions/about	https://www.nature.com/articles/s41558-020-00976-6#Sec8 "Global maps of twenty-first century forest carbon fluxes" (Harris et al., 2021)
17	Forest carbon removals	Global Forest Watch	Global forest carbon removals by forest sinks	Modelled forest carbon removals from the atmosphere	raster continous	Global	30 m	updated annually	2001-2023	Landsat, MODIS	1) megagrams of CO2 removed/ha, and 2) megagrams of CO2 removed/pixel	https://www.nature.com/articles/s41558-020-00976-6#Sec8 "Global maps of twenty-first century forest carbon fluxes" (Harris et al., 2021) > Methods > Forest definition and extend	R: climate (carbon seq.); C: UNESCO Heritage carbon sinks , forests managed by indigenous	2.2.6.X, 3.2.X.X	"Estimation of uncertainty is currently limited to the Global and biome scales based on available data for estimating uncertainty in the activity data." https://www.nature.com/articles/s41558-020-00976-6#code-availability	https://beta-gfw.opendata.arcgis.com/datasets/gfw::forest-carbon-removals/about	free https://beta-gfw.opendata.arcgis.com/datasets/gfw::forest-carbon-removals/about	https://www.nature.com/articles/s41558-020-00976-6#Sec8 "Global maps of twenty-first century forest carbon fluxes" (Harris et al., 2021)
18	Forest greenhouse gas net flux	Global Forest Watch	Global forest greenhouse gas net flux	Modelled forest greenhouse gas net flux calculated following the IPCC Guidelines for national greenhouse gas inventories	raster continous	Global	30 m	updated annually	2001-2023	Landsat, MODIS	1) megagrams of CO2 emissions/ha, and 2) megagrams of CO2 emissions/pixel	https://www.nature.com/articles/s41558-020-00976-6#Sec8 "Global maps of twenty-first century forest carbon fluxes" (Harris et al., 2021) > Methods > Forest definition and extend	R: climate (carbon seq.); C: UNESCO Heritage carbon sinks , forests managed by indigenous	2.2.6.X, 3.2.X.X	"Estimation of uncertainty is currently limited to the Global and biome scales based on available data for estimating uncertainty in the activity data." https://www.nature.com/articles/s41558-020-00976-6#code-availability	https://beta-gfw.opendata.arcgis.com/datasets/gfw::forest-greenhouse-gas-net-flux/about	free https://beta-gfw.opendata.arcgis.com/datasets/gfw::forest-greenhouse-gas-net-flux/about	https://www.nature.com/articles/s41558-020-00976-6#Sec8 "Global maps of twenty-first century forest carbon fluxes" (Harris et al., 2021)
19	European forest morphology, mosaic and connectivity	figshare	indicators for forest morphology, mosaic and connectivity aggregated per landscape units of 25 x 25 km, per provinces (NUTS 2/3) and per country (NUTS 0)	Indicators for european forest morphology, mosaic and connectivity	vector (shape. country, province or grid)	Europe	25 km / province / country	for three years	1990, 2000, 2006	Sentinel2	morphology: (number of pixels) core, edge, linear, islet. mosaic: (number of pixels or percentage) core natural, mixed natural, some natural. connectivity: (0-1) root probability of connectivity	morphology: morphological shapes of habitat mosaic: landscape pattern types between agricultural, natural, artificial and mixed connectivity: connectedness of habitat patches and of ecological processes	P: Habitat, Extreme Events	2.2.2.3, 2.2.1.X	not mentioned	https://figshare.com/articles/dataset/European_forest_morphology_and_mosaic_1990-2000-2006/13253840	free	https://www.sciencedirect.com/science/article/pii/S1364815213002545?via%3Dihub"A proposal for an integrated modelling framework to characterise habitat pattern" (Estreguil et al., 2014)
20	Areas burnt by wildfires (2000-2017)	EEA	Shape file of european areas affected by wildfires (2000-2017)	European areas directly affected by wildfires (2000-2017)	vector (shape)	Europe	not applicable	once	period 2000-2017	MODIS, Sentinel	polygons of affected areas	not specified	R: Extreme Events	2.2.1.5	not mentioned	https://data.europa.eu/data/datasets/8b864fc4-7eee-4861-afff-4e855d62bc9c?locale=en	free https://climate.discomap.eea.europa.eu/arcgis/rest/services/UAMV/AreasBurntByWildfires/MapServer	
21	ForestEurope: pan-European forest fragmentation	figshare	European forest fragmentation map with trend	TIF of forest fragmentation based on CORINE Land Cover dataset with calculated trend	raster, classified	EU	100 m	about every 6 years	1990, 2000, 2006 2012, 2018	Sentinel2	trend: Background (Non-forest), Seperated (Forest), Continuous (Forest) and changes from one to another, water at both times, water at one time only	CORINE Land Cover: 311 - Broadleaved forest, 312 - Coniferous Forest, 313 - Mixed Forest, 324 - Transitional Woodland-Shrub	P: Habitat, Extreme Events	2.2.2.3, 2.2.1.X	"The results of the change detection directly depend on the accuracy of the CLC land cover classification [...]" https://op.europa.eu/en/publication-detail/-/publication/3e0e3db7-0f37-11ea-8c1f-01aa75ed71a1/language-en	https://doi.org/10.6084/m9.figshare.c.4779500.v1	free https://figshare.com/collections/ForestEurope_pan-European_forest_fragmentation/4779500/1	https://op.europa.eu/en/publication-detail/-/publication/3e0e3db7-0f37-11ea-8c1f-01aa75ed71a1/language-en"An approach for pan-European monitoring of forest fragmentation" (Vogt et al., 2019)
22	Forest net primary production gridded data 200-2010	figshare	The State of Forest Resources across Europe	Net primary production in gC/m^2/yr. Derived from National forest inventory data.	raster, continous	EU	1km	once	period 2000-2012	from national forest inventory data & MODIS	NPP gC/m^2/yr	not specified	P: Biomass, R: Carbon	1.1.X.X, 2.2.6.X	not mentioned	https://figshare.com/articles/dataset/Net_Primary_Production/3822321	free	https://www.researchgate.net/publication/304611247_Creating_a_Regional_MODIS_Satellite-Driven_Net_Primary_Production_Dataset_for_European_Forests Moreno, A., Neumann, M., Hasenauer, H., 2016a. Forest structures across Europe. Geosciences Data Journal 4, 17–28
23	European average diameter at breast height gridded data 2000-2010	figshare	European average diameter at breast height gridded data 2000-2010	Mean DBH of all trees within a cell in cm and standard deviation.	raster, contir	EU	0.133°	once	period 2000-2010	from national forest inventory data & MODIS	DBH [cm], stddev [cm]	based on data by Moreno et al. 2017 (Forest Structures across Europe)	P: Biomass	1.1.X.X	not mentioned	https://figshare.com/articles/dataset/Diameter_at_Breast_Height/3822306	free	https://www.researchgate.net/publication/326687444_Climate_limits_on_European_forest_structure_across_space_and_time
24	ForestClim	figshare	Bioclimatic variables for microclimate temperatures of European forests	offset for minimum, mean and maximum temperature between sub-canopy temperature at 15 cm above the surface and free-air	raster, continous	EU	25m	once	period 2000-2020	SoilTemp database, E-OBS data	mean annual temperature, mean diurnal range, isothermality, temperature seasonality, maximum temperature of warmest month, temperature annual range, mean temp of wettest quarter, mean temp of driest quarter, mean temp of warmest quarter, mean temp of coldest quarter	based on the 2015 forest-type map of the Copernicus	P: Habitat; R: Climate, Soil	2.2.2.3, 2.2.6.X, 2.2.4.X	not mentioned	https://figshare.com/articles/dataset/ForestClim_Bioclimatic_variables_for_microclimate_temperatures_of_European_forests/22059125	free	https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.16678 https://onlinelibrary.wiley.com/doi/10.1111/gcb.15892
25	Wood production maps for European forests	European Forest Institute	map of european wood production for 2000-2010	predicted volumes of wood production, based on statistics collected for 29 European countries from 2000 to 2010	raster, continous	Europe	1 km	once	period 2000-2010	Fieldwork (forest inventories)	m 3·ha-1 land·yr - wood production	Based on forest map by Pekkarinen et al. (2009): FAO / CLC forest definition	P: Timber	1.1.1.3	> 70% of variance explained	https://efi.int/knowledge/maps/woodproduction	free https://datadryad.org/stash/dataset/doi:10.5061/dryad.mk067	
26	European Forest Additional Support Layer (FADSL)	Copernicus	Forest Additional Support Layer (FADSL)	provides information on trees under agricultural use or in urban context	raster, classified	Europe	10m	3 years	2012, 2015,2018	Sentinel-2, Copernicus Tree Cover density, Dominant Leaf type, CORINE Landcover, HRL Imperviousness 2018	Trees predominantly used for agriculturdal practices (broadleaf) and trees in urban context (broadleaf and coniferous)	No MMU, TCD range ofz 10-100% includes only broadleaved trees in agricultural practices and trees in urban context	P: Biomass (food); R: Extreme Events (urban heat island)	1.1.1.X, 2.2.6.2	not been assessed, depending on inputs´ accuray	https://land.copernicus.eu/en/technical-library/hrl-forest-2018/@@download/file	free access - but no download link found	The layer is derived through a spatial intersection of the 10m DLT and TCD layers with CLC 2018 and Imperviousness Degree 2018.
27	FAOSTAT Landuse	FAOSTAT	statistical data on annual Landuse from national inventories	contains data on forty-four categories of land use, irrigation and agricultural practices and five indicators relevant to monitor agriculture, forestry and fisheries activities at national, regional and Global level	CSV	Global	/	annually	1961-2022	national inventories	forest land/ naturally regenerating forest/ planted forests	FAO	P: Biomass, Water, Habitat; R: Pollination, Biodiversity,	1.1.X.X 4.2.X.X, 2.2.2.3, 2.2.2.X, 1.2.X.X,	not mentioned	https://www.fao.org/faostat/en/#data/RL	free	CSV/ XLS files
28	Land Cover CCI Clima	ESA	Global Land Cover timeseries with 23 classes from 1992-2020	Land Cover time series 1992-2020	raster, classified	Global	300m	annually	1992-2020	MERIS, Spot Vegetation, Proba 5, AVHRR	23 classes. Tree cover differentiated between broadleafed and needleleaved, evergreen, deciduous and different cover degrees (<15%, 15-40%, >40) Additional mixture classes with other landcover classes like cropland, shrubs, herbaceous, flooded areas	not specified	P: Biomass, Water, Habitat; R: Pollination, Biodiversity,	1.1.X.X 4.2.X.X, 2.2.2.3, 2.2.2.X, 1.2.X.X,	overall Accuracy: 71.45%	https://maps.elie.ucl.ac.be/CCI/viewer/index.php	free: https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-land-cover?tab=form	Accuracy assessment based on GLOBCOVER 2009 as reference data
29	ESA WorldCover	ESA	WorldCover Version 1, WorldCover Version 2	first global land cover products for 2020 and 2021 at 10 m resolution	raster, classified	Global	10m	annually	2020, 2021	Sentinel1, Sentinel2	11 classes: Tree cover,Shrubland, Grassland, Cropland, Built-up, Bare / sparse vegetation, Snow and ice, Permanent water bodies, Herbaceous wetland, Mangroves, Moss and lichen	classes according to UN-LCCS system tree cover >10%, including plantations	P: Biomass, Water, Habitat; R: Pollination, Biodiversity, Soil	1.1.X.X 4.2.X.X, 2.2.2.3, 2.2.2.X, 1.2.X.X, 2.2.4.X	for tree cover producer's accuracy: 91,9% and user's accuracy 80%	https://viewer.esa-worldcover.org/worldcover/?language=en&bbox=-225,-69.59589006237648,225,69.59589006237647&overlay=false&bgLayer=OSM&date=2024-08-08&layer=WORLDCOVER_2021_MAP	free: https://viewer.esa-worldcover.org/worldcover/?language=en&bbox=-225,-69.59589006237648,225,69.59589006237647&overlay=fa&bgLayer=OSM&date=2024-08-08&layer=WORLDCOVER_2021_MAP	Different algorithm versions were used to generate the 2020 and 2021 WorldCover maps. Consequently, changes between the maps include both real changes in land cover and changes due to the algorithms used
30	Forest/Non-Forest Map	JAXA	Global 4-class PALSAR-2/PALSAR Forest/Non-Forest Map	generated by classifying SAR image (backscattering coefficient) in the global 25m resolution PALSAR-2/PALSAR SAR	raster, classified	Global	25m	annually	2007-2020	PALSAR-2	Dense Forest, Non-dense Forest, Non-Forest, Water	FAO	P: Biomass, Habitat,	1.1.X.X, 2.2.2.3	>90% for Europe	https://www.eorc.jaxa.jp/ALOS/en/dataset/fnf_e.htm	free: https://developers.google.com/earth-engine/datasets/catalog/JAXA_ALOS_PALSAR_YEARLY_FNF4#bands	accessible via GEE free to use, for research just credit to JAXA required https://earth.jaxa.jp/en/data/policy/
31	Global Land Cover and Land Use Change	GLAD	GLAD Global Land Cover and Land Use Change 2000-2020	quantifies changes in forest extent and height, cropland, built-up lands, surface water, and perennial snow and ice extent from the year 2000 to 2020 at 30-m spatial resolution.	raster, continous	Global	30m	annually	2000-2020	Landsat, GEDI	percent short vegetation, tree height for stable tree cover, tree height after disturbance, tree height for new tree cover, Water, 6 Landcover classes	woody vegetation greater than 5 meters in height definition includes wildland, managed, and planted forests, agroforestry, orchards, and natural tree regrowth.	P: Biomass, Water, R: Pest and Disease, Extreme Events, C: Recreation	1.1.X.X, 4.2.X.X, 2.2.3.X, 2.2.1.X, 3.1.X.X,	2019 forest height model: RMSE = 6.6 m to GEDI, RMSE = 9.07 m; to ALS 2020 forest height: RMSE = 6.75 m to GEDI forest extent: 97% overall, >93% users's accuracy	https://glad.earthengine.app/view/glcluc-2000-2020#lon=9.381070367730908;lat=10.55540125050857;zoom=5	free: https://storage.googleapis.com/earthenginepartners-hansen/GLCLU2000-2020/v2/download.html	
32	Tree Cover Change	NASA	Global Forest Cover Change (GFCC)	provides tree canopy information and can be used to understand forest changes	raster, continous	Global	30m	5 years	2000, 2005, 2010 2015	Landsat 5, Landsat 7	provides tree cover percentage, Tree Cover Index, Tree Cover Error	woody vegetation greater than 5 meters in height, no tree cover density threshold	P: Biomass, Water, R: Pest and Disease, Extreme Events, C: Recreation	1.1.X.X, 4.2.X.X, 2.2.3.X, 2.2.1.X, 3.1.X.X,	OA for temperate forests >90%	https://lpdaac.usgs.gov/products/gfcc30tcv003/	free: https://developers.google.com/earth-engine/datasets/catalog/NASA_MEASURES_GFCC_TC_v3#description	
33	Forest Cover Fraction	University of Hamburg	Global Forest Cover Fraction (MOD44B) 2000-2022	contains the forest cover fraction (FCF) derived from observations and products of the MODIS Sensor aboard EOS-TERRA	raster, continous	Global	250m	annually	2000-2022	MODIS	100% forest cover fraction = grid cell entirely covered by forest; 0% forest cover fraction = grid cell does not contain any forest. Additionally data layers of the percentage vegetation cover fraction (VCF) as well as of the percent fraction of non-vegetated surfaces (natural or build-up)	forest = light penetration to the ground as compared to "crown" cover which describes the amount of the ground which is encompassed by the tree's crown regardless of whether light penetrates	P: Biomass, Habitat,	1.1.X.X, 2.2.2.3	not been assessed	https://lpdaac.usgs.gov/products/mod44bv061/	free: https://icdc.cen.uni-hamburg.de/thredds/catalog/ftpthredds/modis_vcf/Global_0.5deg/catalog.html	
34	European forest disturbance map	TUM	European forest disturbance map and forest cover map at 30m resolution	maps of annual forest disturbances across 35 European countries derived from Landsat satellite data.	raster, continous	Europe	30m	once	period 1986-2020	Landsat 4/5/7/8	forest cover: at least once during time period covered by forest disturbance size, frequency and severity disturbance per pixel mapped only once during time span (+ year of disturbance)	not specified	R. Extreme Events, Pest and Disease	2.2.1.X, 2.2.3.X	overall of the map: 92.5 ± 2.1% 14.6 ± 1.8% commission error 32.8 ± 0.3% omission error for detection of disturbances		free: https://zenodo.org/record/7080016	Publication: https://www.nature.com/articles/s41893-020-00609-y
35	European strom and fire disturbances	TUM	Attributing European forest disturbances to storm and fire	contains maps attributing each disturbance patch of the European Forest Disturbance Map (version 1.1.4) to bark beetle/wind, fire or other disturbances (mostly harvest).	raster, classified	Europe	30m	once	period 1986-2020	Landsat 4/5/7/8	NA = no disturbance, 1 = bark beetle or wind disturbances, 2 = fire disturbances, 3 = other disturbances (eg. Defoliation)	not specified	R. Extreme Events, Pest and Disease, air quality	2.2.1.X, 2.2.3.X, 2.2.6.X	AUC = 0.98, overall accuracy of 92% for classification commission error (storm): 0.07 commision error (fire): 0.13 ommision error (storm): 0.10 ommision error (fire): 0.24	https://zenodo.org/records/8202241	free: https://zenodo.org/records/8202241	
36	Atlas of Forest and Landscape Restoration Opportunities	World Resources Institute	Global current forest Coverage (2000-2009) at 30m resolution	Global extent of forest coverage, including categories of forest density.	raster, classified	Global	250m	once	period 2000-2009	MODIS	forest density classes: closed forest (>45%), open forest (>25% and < 45%), Woodlands (>10% and < 25%) and non-forest	not specified	P: Biomass, Habitat,	1.1.X.X, 2.2.2.3	not mentioned	https://www.wri.org/data/methodology-data-atlas-forest-landscape-restoration-opportunity	web-viewer: https://www.wri.org/applications/maps/flr-atlas/#&init=y	Archived
37	Atlas of Forest and Landscape Restoration Opportunities	World Resources Institute	Global potential forest coverage (2000-2009) at 1km resolution	represents an estimate of where forests would grow under current climate conditions and without human influence	raster, classified	Global	1km	once	period 2000-2009	MODIS, Ecoregions (Olson 2001), Global climate variables	potential forest in different ecoregions in today's climate and without human presence: closed forest (>45%), open forest (>25% and < 45%), Woodlands (>10% and < 25%) and non-forest + information on change from which current forest status (13	not specified	R. Climate P: Habitat, Biomass	2.2.6.X, 2.2.2.3, 1.1.X.X	not mentioned	https://www.wri.org/data/methodology-data-atlas-forest-landscape-restoration-opportunity	web-viewer: https://www.wri.org/applications/maps/flr-atlas/#&init=y	Archived. should be used with caution due to its coarse resolution (1 km), the age of the input data (prior to 2009), and related caveats.
38	Atlas of Forest and Landscape Restoration Opportunities	World Resources Institute	Global potential forest restoration (2000-2009) at 1km resolution	Data on forest condition and current land use were used to derive the map of opportunities for restoration on degraded lands	raster, classified	Global	1km	once	period 2000-2009	Agricultural Land (Pittman 2010), Forest loss (Hansen 2008), Urban areas (LandScan 2005)	Wide-Scale restoration, Mosaic restoration, remote restoration, forest without restoration needs	not specified	R. Climate; P: Habitat, Biomass	2.2.6.X, 2.2.2.3, 1.1.X.X	not mentioned	https://www.wri.org/data/methodology-data-atlas-forest-landscape-restoration-opportunity	web-viewer: https://www.wri.org/applications/maps/flr-atlas/#&init=y	Archived. should be used with caution due to its coarse resolution (1 km), the age of the input data (prior to 2009), and related caveats.
39	Atlas of Forest and Landscape Restoration Opportunities	World Resources Institute	Global Forest condition (2000-2009) at 1km resolution	A comparison of the maps of current and potential forests makes it possible to identify forest condition	raster, classified	Global	1km	once	period 2000-2009	Current forest covergae, potential forest coverage (see above)	Intact forest, fragmented/managed, degraded, deforested	comparison of potential forest coverage and current forest coverage	P: Habitat; R: Extreme Events, Pest and Disease	2.2.2.3, 2.2.1.X, 2.2.3.X,	not mentioned	https://www.wri.org/data/methodology-data-atlas-forest-landscape-restoration-opportunity	web-viewer: https://www.wri.org/applications/maps/flr-atlas/#&init=y	Archived. should be used with caution due to its coarse resolution (1 km), the age of the input data (prior to 2009), and related caveats.
40	Atlas of Forest and Landscape Restoration Opportunities	World Resources Institute	Global land use intensity maps (2000-2009) at 1km resolution	A map of land-use intensity (human pressure) was used to assess opportunities for restoration of degraded lands as well as classify degraded lands according to suitability for different types of restoration	raster, classified	Global	1km	once	period 2000-2009	data: population intensity, built-up areas, pasturelands, croplands, cultivated areas	high: lands with high population density, croplands, and urban areas; moderate: lands with a rural population density between 10 and 100 persons per square km; low: lands with a rural population density less than 10 persons per squarekm	/	P: Habitat; R: Biodiversity	2.2.2.3, 1.2.X.X	not mentioned	https://www.wri.org/data/methodology-data-atlas-forest-landscape-restoration-opportunity	web-viewer: https://www.wri.org/applications/maps/flr-atlas/#&init=y	Archived. should be used with caution due to its coarse resolution (1 km), the age of the input data (prior to 2009), and related caveats.
41	Integrated Global Forest Assessment	Crowther Lab	potential tree cover layer	Global potential tree or respectively forest cover without human presence	raster, binary	Global	30 arcsec	once	published 2019 (not based on specific date)	MODIS, Landsat, Google Earth	Potential tree or respectively forest cover without human presence	not specified	R. Climate P: Habitat, Biomass	2.2.6.X, 2.2.2.3, 1.1.X.X	r ^2 = 0.86 after k-fold cross validation	https://bastinjf-climate.users.earthengine.app/view/potential-tree-cover	Data upon request; Code available: https://code.earthengine.google.com/ee5cf5186b5ad0f659cc7a43054f072c	Publication: https://www.science.org/doi/10.1126/science.aax0848
42	Integrated Global Forest Assessment	Crowther Lab	Potential forest restoration layer	maps show how much additional tree cover could exist outside of existing forests and agricultural and urban land	raster, classified	Global	30 arcsec	once	published 2019 (not based on specific date)	data: Potential tree cover, Hansen forest extent, Globcover	potential areas that are not covered by urban or cropland land use for forest restoration	FAO	R. Climate; P: Habitat, Biomass	2.2.6.X, 2.2.2.3, 1.1.X.X	not mentioned		Data upon request; Code available: https://code.earthengine.google.com/ee5cf5186b5ad0f659cc7a43054f072c	Publication: https://www.science.org/doi/10.1126/science.aax0848
43	Opportunities for forest restoration on degraded lands	WWF	Global Reforestation Potential Map	Potential forest areas include the extent where forest can grow according to climatic conditions and without considering human influence.	raster, classified	Global	250m	once	2009	data: Atlas of Forest Landscape Restoration Opportunities , NESCent grasslands working group, Hansen Forest Gain	Wide-Scale restoration: less than 10 people per square km and potential to support closed forest, Mosaic restoration: moderate human pressure (10-100 pp/km^2) , Remote restoration: very low human pressure (<1 pp/km^2)	reforestation as conversion from non-forest (< 25% tree cover) to forest (> 25% tree cover) in areas ecologically appropriate and desirable for forests	R. Climate; P: Habitat, Biomass	2.2.6.X, 2.2.2.3, 1.1.X.X	not mentioned	https://www.arcgis.com/home/item.html?id=c529c9eb1df140859da92f560ef4b70	free: https://zenodo.org/records/883444	
44	Global Carbon Accumulation Potential	Global Forest Watch	Carbon accumulation potential from natural forest regrowth in reforestable areas	Estimates the rate at which carbon could be sequestered in aboveground live biomass during the first thirty years of natural forest regrowth in potentially reforestable areas (Mg carbon/ha/yr)	raster, continous	Global	1km	once	2017	national inventories, environmental covariates,WWF reforestation map p	aboveground carbon accumulation rates (+ below ground biomass) Estimates the rate at which carbon could be sequestered in aboveground live biomass during the first thirty years of natural forest regrowth in potentially reforestable areas (Mg carbon/ha/yr).	used reforestation extent of Griscom 2017 (WWF reforestation potential)	R: Climate (carbon seq.)	2.2.6.X	R^2 = 0.45, RMSE = 0.80 Mg C ha-1 yr-1	https://data.Globalforestwatch.org/documents/2b1e75c7d6274e448954178b3bc31bea/about	free: https://data.Globalforestwatch.org/documents/2b1e75c7d6274e448954178b3bc31bea/about	Publication: https://www.nature.com/articles/s41586-020-2686-x
45	Forest Landscape Integrity	WCS	Forest Landscape Integrity Index	integrates data on observed and inferred forest pressures and lost forest connectivity to generate the first Globally-consistent, continuous index of forest integrity as determined by degree of anthropogenic modification	raster, classified	Global	300m	once	2019	data: Hansen Global Tree Cover 2000, Hansen annual Tree Cover Loss, Tree Cover Loss by Dominant Driver, ESA-CCI Land Cover, potential forest cover, GFSAD Cropland, OSM, Global Surface water	quantifies the integrity of a forest by taking in account human pressures like infrastructure, agriculture, usage of forest materials, connectivity. Low integrity (0-6), medium integrity (6-9.6), high integrity (>9.6)	forest = woody vegetation taller than 5m (part of FAO)	P: Habitat; R: Pest and Disease, Extreme Events	2.2.2.3, 2.2.3.X, 2.2.1.X	not mentioned	https://www.forestlandscapeintegrity.com/	upon request: https://www.forestlandscapeintegrity.com/download-data	Publication: https://www.nature.com/articles/s41467-020-19493-3
46	Hybrid Forest Mask	IIASA	Global hybrid forest mask for the year 2000	combining diverse forest cover datasets through geographically weighted regression	raster, binary	Global	1km	once	2000	MODIS, landcover data, crowdsourced data	three different hybrid maps were produced: two consistent with FAO statistics, one at the country and one at the regional level, and a "best guess" forest cover map that is independent of FAO	FAO	P: Biomass, Habitat,	1.1.X.X, 2.2.2.3	OA: 93%		**not found yet**	Publication: https://www.sciencedirect.com/science/article/abs/pii/S0034425715000644
47	Forest Condition Monitor	TUM	European Forest Condition Monitor	Using Remotely Sensed Forest Greenness to Identify Hot Spots of Forest Decline in Europe	raster, continous	Europe	250m	constantly updated	2001-2023	MODIS NDVI, CORINE LC	forest greenness as quantiles of all observations per pixel, relative rank	none	P: Habitat; R: Extreme Events, Pest and Disease	2.2.2.3, 2.2.1.X, 2.2.3.X	not mentioned		web-viewer: http://interaktiv.waldzustandsmonitor.de/	publication: https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2021.689220/full

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Annex 3: Guideline and template of country reports

Guideline how to fill in the country report

The country portfolio should serve as first input information for the following tasks in WG1 "Data and knowledge" in DSS4ES:

- T1.1: EU-wide review of existing digital technologies for landscape inventorying and monitoring.
- T1.2: Review of "Internet of things" and Big Data for landscape management.
- T1.3: Evaluate global forest databases and national forest inventory data, assess data quality, identify missing data components and verify and validate knowledge base to harmonize the data for common uses.

A report submission to COST is due by **March 2025** that will cover aspects of these tasks. The collected country reports (the country portfolio) will be complied / merged by the WG 1 leader and submitted as one report to COST. **Please submit your individual country report latest until 10th September 2024 to:** janina.kleemann@geo.uni-halle.de

In DSS4ES, we are planning to look at the transitional areas between forest and other land uses, e.g. agriculture or urban areas. In these transitional areas, different functions and services of ecosystems can overlap or even new functions and services can emerge (e.g., edge effects) due to its mixed land use and land cover character. Furthermore, new synergies and trade-offs between these different land use types could occur. Please check for more information the MoU (project description) of DSS4ES.

In this country portfolio, we aim at looking at – primarily spatial – data of landscape information **on national level** that can be directly or indirectly related to forest. It does not need to be only remote sensing data but it can be any kind of spatial data on national level. We focus on the national level in order to keep the workload for the reporting low (at first stage). We understand that you might be aware of many different projects at different scales but these data might be added later in the process of DSS4ES.

In order to avoid double work, **members of the same country could cooperate to fill in the country report together.** You can find your country partners in e-COST. However, you might have different expertise within your country, e.g. one expert is specialist in forest and the other in agriculture – you may fill in the table according to your expertise differently where you can also fill in the table separately.

---------- **How to fill in the country report**----------

Your country: Please enter here the name of the country for which you will fill in the report (for which you are representative in DSS4ES).

Author(s) of this report + institutional affiliation(s): Please enter here the names of COST members (or beyond) who contributed to the report in order to acknowledge their contribution. The order of authors can reflect the level of contribution (strongest contribution as first author). Please also enter your/their institutional affiliations (usually, it is the place where you are employed).

Date of final changes made in this document: Please enter here the date where final changes were made in this report in order to document the topicality; this can be also the submission date to the WG 1 leader.

Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1): Here, you can enter text of Table 1 as summary – which perception of data availability do you have or which experiences did you made while filling in Table 1? What was striking for you while filling in Table 1? It will also potentially help us to better understand how you have filled Table 1. This text can be combined with the following section "Data gaps / data problems". Please write the text in a way that we can see to which column / category in Table 1 you are referring to.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1): Here you can write specifically to which scale, for which time period, for which landscape/land use type or ecosystem services, etc., data have been less or more available in comparison to other categories. Which spatial data were better accessible or available than other spatial data? Please write the text in a way that we can see to which column / category in Table 1 you are referring to.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text): Here, you can write a text with future direction / outlook. What needs to be done to improve data availability, accessibility, data quality, etc. of your country on national level in the frame of DSS4ES? If you like, you can also refer to data availability, accessibility, quality, research needs in general in the frame of DSS4ES but please mention it specifically in the text (to which scale, level, country you are referring to).

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Table 1: Overview of available forest-related spatial data of your country on national level for DSS4ES. Please mark the columns / row 1) with "—" where no data were available and 2) with "?" where no data were identified (data might be there but you could not find it.) *You can also use the Excel table and send it as attachment if space is not sufficient here. In addition, you can add forest-related data on global level or general data that could be useful in the frame of DSS4ES.*

Data name	Institution	Product	Description	Product type or data type	Spatial coverage	Spatial resolution or scale	Frequency of data acquisition	Years	Sensor or data base	Description / classes of land use / forest	Used land use / forest definition	Suitable for which ecosystem services (ES) to be assessed	Producer accuracy of data (%)	Access to data	Link / Reference to the data	Comment
Common name of data (or short version) according to the website, e.g. Copernicus Land Monitoring Service	It is the institution which creates /provides the data, e.g. Copernicus	E.g., Global Forest Map	Short and precise description of the data	E.g., raster-classified, continuous, vector data	Primarily on national level (if not available, second, on province or district level)	E.g., 25m, 100 m, points every 2 km etc.	E.g., annually, periodically	For which years data are available, e.g., 2015, 2023	E.g., sensor: TanDEM-X, Sentinel -2; data base: Land Cover Characteristics database (GLCC) from AVHRR	E.g., classes: canopy cover > 90%, canopy cover 10-90%; forest cover, tree density; closed forest, open forest, woodland	Please enter here the underlying land use / forest definition of the data / product, e.g. FAO forest definition	You can enter the ES for which the specific data can be potentially used (for an ES analysis) or is already used, e.g. biomass, recreation, water infiltration	The map accuracy from the point of view of the map maker (the producer), e.g., 72% - 89%	Restricted (by registration only, by payment only), no access, open access	Link to the Website /download	Any comment you want to make related to data in the specific row

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Annex 4: Generic terms and terminologies that were used in the country reports

Product type or data type	**Other Terminologies that were used in the country reports**
Spatial Raster	Raster Data, Raster, WMS Mapserver, spatial data, spatial map, Mapserver, raster classified, raster continuous, mapping, raster binary, GRID, GeoTIFF, Orthophotos, Map, Interactive maps, map applications, Cartography
Spatial Vector	Vector data, vector, GIS database (shp), GIS database (gdb), ESRI Shapefile, WMS, WFS, Shape, ESRI FileGeodatabase, GML, Shape file, Geodatabase (gdb), GIS Layers, map
Statistical Database	Database, numerical data, qualitative data, statistical estimates, non-spatial, csv/xlsx, Excel, xml, statistic, Forest Management Plant, tables/graphs, attribute data, field survey
Text	Brochure, Report, documentation
Spatial Point Cloud	LAS point cloud, LIDAR point cloud
Spatial coverage	**Other Terminologies**
National level	Countries Name, National level map, Forested areas (national), Coillte management areas, Whole Country, Country Scale, National, Nationwide
Regional level	Entity level
Provincial level	Cantonal level, Galicia (Spain), parts of…
Others	Plot level, stand level, NUTS1, NUTS3, scattered samples, N / A
Frequency	**Other Terminologies**
Daily	
Every x days	
Monthly	
X times a year	
Annually	Annual updates, yearly, every year, annual
Every x years	~ x years, x years
Decadal	every 10 years, ~10 years
Regularly updated	Continuously updated, periodically updated, permanently updated, permanently, systematically updated,
Not periodically	Non-regular, x years available, updated irregularly, not determined, updated as needed, dynamically updated, long term
Once	One year only, not planned, not updated, one time, not applicable
NA	n/a, N/A
Spatial resolution of scale	**Other Terminologies**
other	High, x%,
334:20:00	1:200.000 -> 1:20000, 20000 for Spatial Vector
10	10m, 10x10m for spatial Raster
1000	0.1ha, 1km for spatial Raster
25cm	0.25 for spatial Raster
4	4pnt/m2 for Spatial Point Cloud
Access to Data	**Other Terminologies**
open access	Free, online, link, open, registration needed, public access, open source
restricted	Limited, once per year, upon request, partially open, partially accessible, viewing is open, available upon agreement, public access restrictions
not available	Not open access

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Annex 5: Country Reports (countries alphabetically sorted)

This annex contains the text files provided by the authors of the countries about a) Short conclusion on the documentation of the spatial data / data bases of the specific country, b) Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. of the country, and c) Recommendations to improve the data base in the frame of DSS4ES. The table of the respective country (Table 1 in the template of Annex 3) with the information about the data (sets) is stored as Excel file in a data repository here: http://dx.doi.org/10.25673/1914118-9

1. Albania
2. Austria (no text file provided but data stored as Excel file)
3. Bosnia and Herzegovina
4. Czech Republic
5. Germany
6. Ireland
7. Italy
8. Latvia
9. Lithuania
10. Poland
11. Portugal
12. Romania
13. Serbia
14. Slovakia
15. Slovenia
16. Spain
17. Sweden
18. Turkey / Türkiye

1. Country Report: Albania

Author(s) of this report + institutional affiliation(s):

- Prof. Assoc. Dr. Jostina Dhimitri, Department of Geography, Faculty of History and Philology, University of Tirana, Albania
- Assoc. Prof. Albina Sinani, Department of History, Anthropology and Geography, Faculty of Education and Social Sciences, "Eqrem Çabej" University of Gjirokaster/Albania 6001

Date of final changes made in this document: 10 Oct. 2024

Please note that Table 1 is stored here: http://dx.doi.org/10.25673/1914118-9

Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Forests are not only vital components of our natural ecosystems, but they also play a crucial role in the continuity of life and well-being of Albanian society. The National Forestry Agency, in Albania, has as its mission the good governance of forests at the national level, their preservation and development, the sustainable and multifunctional use of resources in the national forest fund, as a natural asset of national importance.

The documentation of spatial data related to Albania's forest and pasture resources provides insights for sustainable land management and decision support systems (DSS4ES). In 2021, Albania's forest and pasture fund encompassed a total area of 1,716,824 hectares, representing 59.7% of the country's total land area. Within this fund, forests accounted for 1,146,724 hectares, which is 66.8% of the total forest and pasture area. Pastures comprised 448,750 hectares, equating to 26.1% of the forest and pasture fund. Notably, areas classified as forest vegetation and unproductive lands made up 121,350 hectares, or 7.0% of this fund. The inclusion of forests within protected areas has led to an increase of 94,882 hectares compared to 2020, highlighting the importance of conservation efforts. According to the National Forest Inventory (IKPK), forests in Albania cover 65% of the national territory, which translates to approximately 0.65 hectares per capita, significantly higher than the European average of 0.36 hectares per capita. In Europe, forests span 227 million hectares, covering around 35% of the total area (Forest Europe, 2020). The national forest fund, as reported by IKPK in 2021, has a total area of 1,197,000 hectares, with a standing volume of 57.7 cubic meters. This data emphasizes the important role of forests in Albania's ecological and socio-economic landscape, providing valuable resources for energy, tourism, and biodiversity conservation, while also informing policies and management strategies for sustainable development.

The information in Table 1 summarizes more than 10 data sources on forests in Albania, which are qualitative and quantitative, absolute and relative ones, and can potentially be included in COST analyses.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Based on the information provided in the table 1 regarding various data sources on forests in Albania, several data gaps and problems can be identified. Addressing these gaps is essential for improving the quality of analyses and decision-making processes in forest management and ecosystem services assessment.

a) Although some data sources touch on ecosystem services like biomass and CO2 sequestration, evident in the technology used for heating, where according to the 2011 Census, about 63% of households in rural and urban areas used stoves for heating with firewood.

b) There is a lack of comprehensive assessments that quantify these services across different forest types.

c) While documents like the Forest Policy Document for 2030 provide insights into forest management strategies, there is a need to find more detailed information on the implementation and effectiveness of these policies at local level.

d) Most data in this table (1) are presented at a national level, which may obscure important local variations in forest health and usage. Local assessments are essential for tailoring management strategies to specific regions and communities.

e) While some datasets are available online, there may be barriers to access, such as language or technical requirements. Making data more user-friendly and widely accessible would promote better engagement from stakeholders and researchers.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

Improving the database concerning forests in Albania is crucial for enhancing decision-making processes in forest management and ecosystem services assessment. Based on the identified gaps and problems, some of the recommendations might be proposed:

a) Conduct detailed assessments that quantify various ecosystem services provided by forests, including carbon sequestration, biodiversity support, and recreational value. This could involve establishing a standardized framework for measuring these services across different forest types, enabling more robust comparisons and evaluations. Utilize remote sensing and GIS technologies to gather more precise data on forest health, biomass, and changes over time. This technology can enhance the spatial resolution of ecosystem services assessments and provide timely information.
b) Develop a systematic approach to monitor and evaluate the effectiveness of forest management policies. This could include establishing performance indicators and regular reporting mechanisms that provide feedback on policy outcomes at local levels. *Stakeholder Engagement*. Foster collaboration among stakeholders, including government agencies, local communities, and NGOs, to ensure that the policies are effectively implemented and adapted to meet the needs of diverse forest users. Engaging local communities can enhance compliance and improve the relevance of policies.
c) Implement initiatives to gather data at local and regional levels, allowing for a more nuanced understanding of forest conditions and management practices. Local inventories and community-based monitoring programs can help capture variations that national data may overlook. *Capacity Building*. Provide training and resources to local stakeholders and organizations on data collection methodologies and the importance of local assessments. This will empower communities to contribute to data gathering and improve local forest management practices.

Other Notes:

1. Request 1. The forest area in Albania is about 1 million ha, occupying about 36% of the country's area, with an average of 0.36 ha/inhabitant. This figure is relatively average compared to other countries in the region, where Montenegro has the highest with 0.9 ha/inhabitant, Croatia with 0.44 ha/inhabitant and Serbia with 0.3 ha/inhabitant. The estimated timber volume is around 55 million m3, with a decrease of 20 million m3 from 2005, thus reducing the quality of our forests and characterizing us as a "forest rich country". In recent years, forests have taken an ever-increasing place in the political agenda and governance priorities, realizing the importance of forests for the quality of life, economic and social development of the country and natural balances. In 2022, the total volume of forests is estimated at around 54,063,000 m3, of which 94.0% of this volume consists of public forests and 6.0% of private forests.

The area of the forest fund is generally the same, while the volume has been in an alarming decline, where only for the period 2006-2017 it has fallen by 32%, currently resulting in less than 55 million m3. This shows that we have an available forest fund area, but no forests.

In 2022, the largest area of the forest fund will be occupied by conifers with 49.8%, followed by other species with 35.9% and conifers with 14.3%.

Currently, the area of the forest fund in 2017, according to INSTAT, consists of a total area of 1,051,871 Ha (where 97% are public forests or 1,023,091 ha, and only 3% private or 28,780ha).

The typologies of the forest fund consist of 36% trunks, 28% stumps and 36% bushes. From the data of INSTAT, it results that 14% of the area of the forest fund is occupied by coniferous forests (where 9% is black pine, 1% spruce and 4% other conifers). The largest part of the surface of the forest fund, namely 50%, is occupied by pines (16% oak, 29% oak, 0.17% poplar and the rest by other pines). While 36% is covered by bushes (where the gorse has 12.6% of the surface, 9% is taken and other bushes 14.23%).

While the age of the forests consists of 22% trunks over 100 years old, 6% stumps over 40 years old and 30% bushes over 20 years old. It is noted that because of overexploitation, Albania is currently characterized by the fact that it has young forests. The volume of forests has a value of about 55 million m3 per foot and according to the typologies, it turns out that 84% of the volume consists of trunks, 10% of the volume consists of stumps and 6% of the volume consists of bushes.

The extent of the forest fund according to the four major development regions in Albania (*as evidenced by their extent according to the colors on the map of Albania*), results in 31% of the territory in the Northern Region, 19% of the territory in the Central Region, 31% of the territory in the Region South-East and 19% of the territory in the South-West Region. Referring to the 12 districts of the country, the distribution of the area of the forest fund is presented according to the following chart, where Shkodra District leads with 20% (*over 210 thousand ha*), followed by Elbasan and Korça with 13% each, Dibra 12%, Lezha 11%, followed by Kukës District with 10% of the forest fund (with over 100 thousand ha). According to the ranking of the counties, it turns out that only 6 counties occupy about 80% of the total area of the forest fund in Albania, while the remaining 20% of the forest fund is occupied by the other 6 counties together (Gjirokastër with 6%, followed by Vlora, Berati, Tirana, Durres and to finish with Fier County with only 1%).

Protected natural and tourist areas in our country are considered protected land and water due to the biological diversity of the natural and cultural assets they offer. Protected areas in 2022 occupy a total area of 608,684 hectares, representing 35.1% of the area of the forest and pasture fund as well as about 21.2% of the total area of the country. During the year 2022, after the process of revising the borders and evaluating the environmentally protected areas, the network of protected areas is defined with 4 (four) categories from the 6 (six) that were in 2021, whereas because of this evaluation are reflected changes in both their number and surface area. In 2022, the largest area of protected areas was occupied by national parks with 49.5% of the total area, followed by managed nature reserves with 36.8%, protected landscapes with 13.45% and natural monuments 0.25 %.

2. Request 2. According to a study conducted by the Albanian Center for Economic Research, firewood covers 68% of energy needs in rural areas during winter and 53% during summer (*when used as a source of cooking*).

The forest sector has never entered the list of strategic priorities, in parallel with other natural resources such as water or land. A phenomenon encountered in the rural population is precisely the high consumption of wood for heating and cooking, where according to the 2011 Census, about 85% of families in rural

areas use firewood for heating. Forest management is currently done by 61 municipalities, except for about 15% of the forest funds that are Protected Areas and managed by AKZM (National Agency of Protected Areas).

In the last twenty years, the national forest fund has decreased by 30 million m3 (*about 1.5 million m3/year*), or by 40% of it, and the area with virgin forests has decreased by 85%, or from 70 thousand ha that was in 1997, today we only have about 11 thousand ha. The cutting of forests for firewood is about 2-2.5 times more than their annual growth.

3. Request. 3**:** Forests are an important resource for promoting tourism, creating recreational facilities and performing many sports activities, so the consequences would be directly evident in tourism, with image/beauty damage. Positioning forests as a government priority, as one of the important and vital resources and increasing awareness and sensitization on forests. After 1945, afforestation campaigns were extended to mountainous and lowland areas, mainly along the banks of rivers and in the hills around cities. Over 80% of the afforestation was done with conifers (wild pine and soft pine). The cultivation of forests with Mediterranean pine continued until 1991. Forest improvements consisted of clearings, cuttings, re-cuttings, releases, care and thinning of timber mainly in forests of oak. To preserve forest reserves, the amount of timber cut or damaged should not exceed the average growth rate of the forest.

But the use of wood for heating and cooking in rural areas has led to the cutting for decades of an amount of wood material twice the productive potential. This has led to the reduction of the inherited forest fund over the years, damage to the forest structure and the quality of timber. However, the use of wood for heating, mainly in rural areas, decreased after 1990, because of the rural exodus of the population. This has influenced the improvement of the natural growth of forests. Meanwhile, the demand for construction materials has decreased compared to 1989, because there is no more demand for poles from the mining industry, for buoy branches, etc.
Secondary forest products include spontaneous medicinal and aromatic plants, plant essences, tannins and resins, resins, etc. for the collection, processing and trading of medicinal plants, with activity in the country and abroad. The leverage of medicinal plant collection is twofold: as a source of income for the rural population and as products with export value.
During the period 1990-1994, there were no investments for mountain systems. They were restarted after 1994, by donors, the Ministry of Environment, Forestry and Water Management, the World Bank, etc., and focused on the maintenance of mountain stone shelters. The forest fund was severely damaged during the transition period, especially from the abusive cutting of pine, fir, oak, and log forests. This process continues in forests that do not have municipal status. The almost complete lack of investment in forests during the transition was accompanied by negative consequences for secondary forest products, biodiversity (*massive burning, uncontrolled hunting, etc.),* forest quality (*lack of clearing, improvements, new afforestation*), bringing about the degradation of forest surfaces, the activation of erosive processes, etc. As a result, the forest area per inhabitant has decreased.

Forests are a source of income and a source of seasonal employment for the entire rural community. For the sustainable development of the forest economy, it is important:
-increase, renewal and protection of forest wealth.
-the strengthening of technical and legal measures for the conservation and good administration of forests, through - the licensing of serious private entities.

2. Country Report: Austria

Only Table 1 available. Table 1 is stored here: http://dx.doi.org/10.25673/1914118-9

3. Country Report: Bosnia and Herzegovina

Author(s) of this report + institutional affiliation(s): Vladimir Stupar, University of Banja Luka, Faculty of Forestry

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Please note that Table 1 is stored here: http://dx.doi.org/10.25673/1914118-9

Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Four datasets were collected all in vector format, three in polygon and one in point vector format. Two datasets are available at the entity level, and the other two at the state level. One dataset is from 1960s, the other is from 2006-2009, while other data are updated every 10 years. The majority of datasets have high declared accuracy (around 97%), however this is to be taken with caution. No data is publicly available (in hold of public enterprises), while one set is not even published so its data were never practically used.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

The biggest problem is that the data made every ten years is not publicly available, and is based on NFI from 1960s. Quality of all data is questionable, owning it to the methodology used or technical issues of data acquisition. This is especially true for spatial data about non-forested areas that are eligible for reforestation. Also, there is a lack of biodiversity data, weather it is habitat diversity or species diversity.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

The database could be improved by adding new data categories into the data acquisition methodology (habitat types at the level of EUNIS habitats/European vegetation framework or similar international classification system). Also the database would benefit from the use of remote sensing techniques which are not used or not used enough in BiH forestry. Also, there is no centralized mechanism for data storage and exchange at the national level.

4. Country Report: Czech Republic

Author(s) of this report + institutional affiliation(s):

- Michal Synek and Jan Máslo, The Forest Management Institute Brandýs nad Labem, Czech Republic

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Forests are well covered by different data sources in the Czech Republic (NFI, remote sensing, forest management plans etc.). The most accurate, up-to-date, and comprehensive source of information on Czech forests is the national forest inventory. Over its more than 20-year history, the Czech NFI has taken a series of methodological steps to meet the requirements of international reporting, such as adopting the specific forest definition (FAO FRA) and setting a strict time schedule of aerial photointerpretation and field survey (since 2011) that ensures not only spatial, but also temporal representativeness of NFI data and results. Since 2016, the Czech NFI has become a continuous survey, so a representative sample of plots is surveyed in every year with five-year plot revisit period, without any interruption. However, the NFI data is not sufficient for a range of information, especially for long time series (back in history) and interactive spatial data. For comprehensive information on forests, it is therefore necessary to use other data sources (Registers and statistics, remote sensing etc.). Nevertheless, it is also essential to have information on landscape where there is no tree cover. Regarding agriculture land, the most reliable source of information is the LPIS (Land parcel identification system). Land cover categories are best covered by the Consolidated layer of ecosystems.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Some data sets do not have a time series and are only available for a limited period. It is not certain whether or when they will be updated. In general, there is lack of spatial data. Most of the data sources focus only on a particular sector and a specific land use. The complexity of quantifying ecosystem functions and services requires a larger data set, considering overlaps between the various sectors. A related issue is the security policy for data exchange and use. Potential data gaps can be assessed based on a methodology, which will be used for valuation of ecosystem services. Synergies between the different data sources and their inter-operability is the main challenge in the upcoming period.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

No comments now.

5. Country Report: Germany

Author(s) of this report + institutional affiliation(s):

- Daniel Gruschwitz, Svenja Dobelmann, and Michael Thiel, Earth Observation Research Cluster, Institute of Geography and Geology, Julius-Maximilians-University of Würzburg, John-Skilton-Str. 4a, 97074 Würzburg, Germany
- Janina Kleemann and Madina Gast, Martin-Luther University Halle-Wittenberg, Institute of Geosciences and Geography, Department of Sustainable Landscape Development, Halle (Saale), Germany

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

In total, 17 datasets were collected on national level for Germany. The majority of datasets (11 items, 65%) were raster data, 5 vector data, and 1 in csv-format (no. 1 in the table). Three datasets were only for the Federal State Baden-Württemberg. At least 6 datasets (35%) are based on the national forest inventory. Nine datasets (53%) area based on Sentinel-1, among others. The spatial resolution ranged from 5m to 2.5 km. The oldest dataset was from 1987 of the national forest inventory but which has been repeated/updated in 2002, 2012, and 2024 (no. 1 in the table). Seven datasets (41%) have an annual update. Five datasets were only once updated – the Dominant Tree Species, stocked wooded land (conducted by the Thünen Institute), forest ownership types, and tree high structure (no. 5, 6,7,13, and 14 in the table). The producer accuracy was for 3 datasets > 90% but we could not identify the producer accuracy for most of the datasets. The majority of datasets seems to be open access (13 datasets, 77%). There are numerous land cover data that are suitable for a variety of ecosystem services. A focus in the data seems to be on carbon (NPP, biomass, etc.), which is particularly suitable for the provisioning ecosystem services energy, material/biomass, and carbon storage.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

There is less information on data/producer accuracy (no information about the data quality) of the Germany-wide data sets compared to the Europe-wide datsets. However, this is often due to data from forestry inventories and field measurements. The spatial resolution is not yet resolved enough to make precise statements about biodiversity or pollination. The cultural ecosystem services are hardly covered, which might be due to the fact that cultural values are difficult to quantify and often contain many different (also non-spatial) aspects. Overall, more ecosystem services-relevant data could be collected, for example, for water, soil or cultural ecosystem services, in addition to the forest-specific data sets.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

In general, it would improve the usage of data when data collection methods, data types and could be used in a comparable format but this has been a common problem in forest-related data. If possible, data accuracy should be added as information to metadata. Data could be enriched by collecting more data that is also related to cultural ecosystem services, e.g. tourism, landscape aesthetics and landscape appreciation. However, also here, we know that this type of data collection is subjective and can vary over time and with different stakeholder groups, age, and generation.

6. Country Report: Ireland

Author(s) of this report + institutional affiliation(s): Francesco Martini (Botany Department, School of Natural Sciences, Trinity College Dublin, Ireland); Markus Eichhorn (School of Biological, Earth and Environmental Sciences, University College Cork, Ireland)

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1): Ireland has a limited forest cover (~11%) compared to most European countries. As a consequence, the datasets available on forests are somewhat limited. We have included some dataset, such as the Irish Soil Information System National Soils Map, which although not directly related to forest can be useful in some contexts. The National Forest Inventory data are available upon request but do not provide the precise location of the plots. In total, there are 11 datasets. Only the National Forest Inventory data are available and collected at regular intervals, although they do not come with a spatial component. We have included them nonetheless as they are the most relevant source for forest data in Ireland. Six datasets are vector and four are raster.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Some datasets do not have a temporal component and are available only for one year. It is unsure whether they will be updated (for example the National Land Cover Map), and in some cases the data were results of one-time projects and does not seem they will be updated. There is a lack of detailed spatial data. Forest Inventories collected by semi-public companies such as Coillte or private actors are not fully available to the public, data are often incomplete, and the temporal components is unspecified at times. There are case studies of ecosystem services modeling or other studies that have been conducted but they are often limited to specific sites as part of research projects.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

Many datasets miss a clear temporal component as they are not produced as part of regular monitoring programmes. Besides the NFI data it seems most datasets are not produced regularly.

Metadata is not always available or easy to access and important information (e.g., accuracy) does not seem to be always present.

7. Country Report: Italy

Author(s) of this report + institutional affiliation(s): Simone Corrado, University of Basilicata

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

In Italy, the spatial data sets relevant for Decision Support Systems for Ecosystem Services (DSS4ES) are primarily obtained from the National Geoportal, which provides comprehensive coverage across the entire country and is generally reliable, though it is not specifically focused on forest data. In contrast, the National Inventory of Forests and Forest Carbon Pools (INFC) offers more specialized data on forests, but its mapping is incomplete, and accessing the data can be challenging. Users must contact the data owners, the Carabinieri Command of Forestry, Environmental, and Agri-food Units (CUFA), and the Council for Agricultural Research and Economics (CREA) to obtain these data.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

One major problem is the inconsistency and irregularity of data updates, which are typically project-dependent and not conducted on a regular basis. This makes it challenging to carry out detailed spatio-temporal analyses, especially for long-term studies or those requiring continuous data over time.

These gaps are particularly evident in the specialized data from the National Inventory of Forests and Forest Carbon Pools (INFC), where the mapping is incomplete and often requires direct contact with data.

Additionally, while the National Geoportal provides a broad range of spatial data covering the entire country, these data sets are not always specific to forests and may lack the resolution or thematic detail required for certain ecosystem service assessments, particularly those involving local-level decision-making or habitat-specific studies.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

As said before, in the Italian context is the irregularity and inconsistency of data updates, which are often dependent on specific projects rather than a systematic approach. This lack of periodic mapping makes it difficult to perform reliable assessments of ecosystem services (ES) over time. To address this, it would be beneficial to establish regular data collection schedules and encourage the integration of remote sensing data to improve data coverage and frequency. The DSS4ES project could play a role in promoting these improvements.

8. Country Report: Latvia

Author(s) of this report + institutional affiliation(s): Ivo Vinogradovs, University of Latvia

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1): Consistent data coverage for forest lands to calculate basic ecosystem services is very scarce at the landscape level. There is no national data with comprehensive coverage applicable for the assessment and mapping of ecosystem services across all land uses. Overall, I am very familiar with the data, as I use it in my daily work, so the low quality and coverage are not surprising.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1): Most of the data is sectoral, focusing on specific land uses. These sectors can spatially overlap, and their precision varies from place to place. Temporal gaps arise from inconsistent data collection and a reliance on manual input. Data on protected habitats could be the most promising to use, but many forest habitats have been cut down due to inadequate legislation.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text): I believe that future data sources should be based on remote sensing data combined with national statistics, with the hope that one day this data will be consistent at the European level. Additionally, for DSS4ES, this combination would provide the most suitable results.

9. Country Report: Lithuania

Author(s) of this report + institutional affiliation(s): Gintautas Mozgeris, Vytautas Magnus University

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Most of the data listed in Table 1 are available from the Lithuanian geospatial infrastructure portal at www.geoportal.lt. Most of the descriptions were based on metadata of each data set. As a rule, most of data sets are open and can be ordered and downloaded from the geoportal. However, most of the data sets are also directly available from the institutions which have developed them upon request. All data sets listed in the table below have been used for mapping ecosystem services by forests and forested landscapes. As a rule, the information from the data sets, used independently or together with other data, can serve as proxies for diversity of ecosystem services. State forest cadaster data holds records on all forest compartments of the country and it has been widely used for scenario modelling, decision support and ecosystem service planning.

There are some specific historical data sets on forest lands mentioned in the table below, which are available directly from the developers and potentially valuable for ecosystem service modelling.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Most of the data sets available from Lithuanian geospatial infrastructure portal are continuously update and can be considered as the optimal sources of information. However, the State forest cadaster is under reforms in Lithuania nowadays. Therefore, the quality of State forest cadaster is declining. Lowest level of relevance is in the private owned forests.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

It is hard to believe, that the DSS4ES will solve the problems with Lithuanian data for forestry and special planning. New approaches in building forest resource information system are planned. To implement the conditions of GHG accounting in LULUCF sector, the development and use of geographically explicit data is coming. The plan is to have a 25x25 (10x10) m virtual sample plot system with key forest characteristic indicated. The information system under development will be fully compatible with the needs for forest management scenario modeling.

10. Country Report: Poland

Author(s) of this report + institutional affiliation(s):

- Andrzej Talarczyk, (1) Forest and Natural Resources Research Centre, Warsaw, Poland, (2) Taxus IT, Warsaw, Poland
- Nugraha Nurrochmat, Warsaw University of Life Sciences, Warsaw, Poland
- Wojciech Kędziora, Warsaw University of Life Sciences, Warsaw, Poland

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Around 80% of Poland's forests are public, most belonging to the State Treasury. Apart from national parks and maritime authorities' forests, all State Treasury forests are managed by a single organization – State Forests Holding. For this reason, Poland has a well-developed system of collecting, processing and sharing information on forests. Forest information systems are computerized and rather sophisticated. Since 2011, a single forest data collection system named Forest Data Bank has been in operation.

Poland has a relatively well-established framework for forest-related spatial data that may support DSS4ES. The key institution is the Forest Data Bank, but it is supplemented by organizational units of the State Forests Holding, General Directorate of Environment Protection, Forest Research Institute, land cadaster departments in county offices and the Chief National Surveyor, Institute of Meteorology and Water Management. All these institutions produce and maintain many high-quality datasets and data products related to forests.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Despite the good spatial data infrastructure (table 1), some notable gaps and issues could hinder effective decision-making:

1. Temporal Coverage and Updates: many datasets are updated periodically but gaps can be noted, especially concerning data on private forests. They are supervised by county offices that often experience budgetary constraints. The frequency of acquisition may also not be sufficient for certain applications requiring near-real-time data.
2. Spatial Resolution: Although many datasets are available at fine spatial resolutions (e.g., 10m to 100m), data with very high resolution is often restricted, limiting its accessibility for detailed, site-specific analysis.
3. Ecosystem Service Assessments: Certain ecosystem services, such as e.g. pollination, recreation, are underrepresented in the available datasets.
4. Data Accessibility: Most datasets are publicly accessible. Some critical data, such as raw National Forest Inventory and forest monitoring data, are subject to access restrictions.

Recommendations to improve the database in the frame of DSS4ES (general or country-specific but please specify in your text):

None at the moment

11. Country Report: Portugal

Author(s) of this report + institutional affiliation(s): Sofia Corticeiro, University of Aveiro

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Portugal has a relatively well-established framework for forest-related spatial data that may support DSS4ES. Key institutions like the Instituto da Conservação da Natureza e das Florestas (ICNF), the Direção-Geral do Território (DGT), and the Instituto Português do Mar e da Atmosfera (IPMA) provide comprehensive datasets covering aspects such as forest cover, fire risk, land use, and protected areas (table 1). The data is generally of good quality, with regular updates (sometimes with a frequency of acquisition to higher) and reasonably high spatial resolution, ensuring its utility for a broad range of applications, from conservation planning to forest management. Several national and European-wide datasets, such as the National Forest Inventory (NFI) and Corine Land Cover (CLC), offer detailed classifications and are accessible for various ecosystem service assessments, including biodiversity conservation, carbon sequestration, and fire risk management. These datasets are typically available in GIS formats, allowing for easy integration into DSS tools.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Despite the good data infrastructure (table 1), there are some notable gaps and issues that could hinder effective decision-making:

1) Temporal Coverage and Updates: While datasets like the National Forest Inventory and Corine Land Cover are updated periodically, the frequency may not be sufficient for certain applications requiring near-real-time data.
2) Spatial Resolution: Although many datasets are available at fine spatial resolutions (e.g., 10m to 100m), data with very high resolution is often restricted, limiting its accessibility for detailed, site-specific analysis.
3) Ecosystem Service Assessments: Certain ecosystem services, such as e.g. soil fertility, pollination, and water purification, are underrepresented in the available datasets.
4) Data Accessibility: Although many datasets are publicly accessible, some critical data, such as high-resolution forest biomass and carbon stock data, are subject to access restrictions.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

To enhance the utility and comprehensiveness of forest-related spatial data in Portugal for DSS, it is recommended to increase the frequency of data updates, particularly for dynamic environmental challenges like climate change and land use changes, and to improve spatial resolution. Expanding the coverage of ecosystem services will allow for more holistic environmental management, and improving accessibility to restricted datasets will facilitate broader use among researchers, public entities and local communities.

12. Country Report: Romania

Author(s) of this report + institutional affiliation(s): Bogdan Popa, Aureliu Halalisan, Nicolae Talpa, Mihai Hapa

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Short conclusions on the documentation of the spatial data / databases from your country for DSS4ES (please write a text here and refer to Table 1):

As of the final changes in the document, there are 4 types of forest-related data of Romania on national level with either available data, limited data or no access at all. Among these 4 sets of data

- 1 database, namely NFI database (hard and complex set of data) is not available for the general public however civil society can use the summary provided on the website and upon requests, might receive additional data.
- The 2nd database which consists of Forest management plans which are compulsory in Romania if you manage forests over 10 hectares, are available to a certain extent on different sources however, upon requested, the National forest administration could provide a set of data for various forest characteristics and in special cases, data sets (management unit descriptions) from forest management plans in forests owned by the states. While state forests are seen as public goods, hardly any institution or body can gather data from private forest owners.
- The 3rd, GHG Inventory, upon request, is an attainable type of data, both estimations of carbon and stand related data at national level.
- 4th, Forest map based on ecosystem units of Romania is a cartography-map type of data, should also be under the form of a raster or vector and upon request, could be obtained since it is owned by the INCDS.

Other data would come from reports of either State forest administration or certification bodies as well as National Institute of statistics which publishes an annual national report on forest statistics.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

There are not so many datasets available, most of them are owned by the Ministry of environment, water and forests. The only available data is what we can find on the internet, mostly reports or any other annual publications or articles. However, upon request, we might get some sets of data that could be used but, it might be the case of it being local or regional, rather than nationally.

The spatial resolution of any data is hardly tackled, not yet considered thus, difficult to make precise statements about biodiversity or forest resilience. Moreover, the cultural ecosystem services are not taken into account, which might be due to the fact that cultural values are difficult to quantify and often contain many different multidimensional aspects and require a lot of finances.

The main important aspect of data availability in the case of Romania is the consistency and reliability of it. As many experts consider, having various types of data done by multiple institutions (e.g. National Institute of Statistics provides a certain type of data coming from official reports but the NFI provides a systematic type of data that covers all of Romania which is considered forests). To this matter, various national and international bodies doesn't know what source is reliable thus they tend to either make a mean or choose whatever fits best (e.g. Eurostat uses NFI but in various research articles or reports, data from National Institute of statistics are preferred).

Recommendations to improve the database in the frame of DSS4ES (general or country-specific but please specify in your text):

- Get data that are important to solve certain issues, not data in general.
- The data accuracy should be given priority since garbage in = garbage out
- Collection methods could be enhanced to consider the socio-cultural function of the forests and extend objectivity but keeping the community wisdom associated with each country.

13. Country Report: Republic of Serbia

Author(s) of this report + institutional affiliation(s):

- **Sonja Tarčak**, BioSense Institute, University of Novi Sad, Serbia
- **Ilija Đorđević**, Institute of forestry, University of Belgrade, Serbia
- **Miljana Marković**, BioSense Institute, University of Novi Sad, Serbia

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Search strategy

As a first step, a search strategy was considered. Two aspects were deemed important for more systematic search: 1) ecosystem services (ES) categories, and 2) institution. Within each ES category, groups of data were identified according to their suitability for use at different scales, i.e. from land cover to tree data. Another way of grouping considered was thematic (e.g. different types of forest vegetation data, biodiversity, soil etc.). After considering the groups of potential data, various information sources were considered: 1) public organisations responsible for forest resources (e.g. the ministry, forestry enterprises), 2) other public organisations whose activities are linked to forests (e.g. nature conservation agencies), 3) NGOs, 3) academic sector.

Data and sources

In total, 33 datasets were found for Serbia (21 for national level, and 12 for regional and provincial level). The majority of datasets are vector data (29 items, 88%), and 3 raster data (9%). For one dataset (distribution of endangered species and habitats in Serbia) the type was not identified. More than half of the data is linked to the forestry information system. The other part was mostly from nature conservation data bases. In many cases, the information on the scale was not found. One product was based on SPOT-5 (10 m resolution), and another one on Sentinel-2 (60 m resolution). The forestry data is updated every 10 years approx. Most of the other data are periodically updated, or are not updated. The oldest dataset dated from 1960, the soil profiles database (from the soil information system), which was periodically updated with new information until 2010. Most of the data is collected in the field, so the accuracy information was not provided.

Serbia has recently entered into the process of building the infrastructure for geospatial data, which should serve for easier communication and data sharing between different sectors and organisations at local, regional and state level, as well as for improved public informing. The process was supported through the EU project "INSPIRATION - Spatial Data Infrastructure in the Western Balkans" (2012-2013), in the frame of the EU INSPIRE Directive. The main organisation responsible for carrying it out (the national spatial data infrastructure) is the Republic Geodetic Authority. Therefore, the first step in screening of the available forest-related spatial data was to check the data available on the national geoportal (https://tmp.geosrbija.rs/en/). This was done by checking the metacatalogue for specific themes (e.g. land cover, habitats and biotopes, environmental monitoring etc.). In total, 11 products related to forests were found on this portal. Most of the data found is a generic type of data (e.g. forest vegetation types, protected areas etc.) shared from public sector organisations. The same data can be also found on geoportals of public sector organisations, mainly public forestry enterprises. The products from public forestry enterprises were also inserted in the table, because the manner of the data representation differs (e.g. only the distribution of forest protected areas is provided by forestry enterprises, while on the national geoportal all protected areas are shown, including non-forest). In total, 11 map products were found on geoportals of public forestry enterprises. The data usage is restricted (data cannot be freely downloaded), and it is not clear in which way it is restricted (is it fully locked for use, or it has to be paid or something else).

Further search was done through the official web pages of public organisations. The forestry sector provides most of the information related to forests as it would be expected. The Ministry of Agriculture, Forestry and Water Management is responsible for the forestry information system (centralised spatial forestry database). The database itself is not freely accessible, but the information on the types of data stored in it can be found in the official documents available online. The database contains several groups of data that are collected depending on the purpose. E.g., one such group of data is from the national forest inventory (NFI). Another group of data relates to forest management planning, and so on. The database is

supplied with information from public forestry enterprises or others managing forests across Serbia. So, it is representative for the national level. It is possible that some data groups would be missing in our table, because they were not mentioned in the documents found online, and we do not have access to the database. The most important source of information for the national level is a recent national forest inventory (NFI). A full list of the NFI data was not typed in Table 1, but only a description of the groups of data contained (in the column 'description'). The same was done for the forest management data. A detailed list of forest-related data collected for the NFI is available in the online document for which the link was provided. Some of this data is available in an Excel file created for the NFI report by FAO. For forest management data, there is no such document for which the link could be provided. A key for data coding in the database (provided by the Ministry) helped in elucidating the types of data available in that database. The maps found on the geoportals of public forestry enterprises are probably based on the same data that is stored in the database.

As for the research products, the time was limited and only a quick search was done in order to identify research institutions delivering these types of products or owning potentially useful databases. In this case, we referred to a research publication that mentions a database (i.e. a product was based on a database). Not many were found, but more comprehensive search would be needed. Similarly, in the case of NGOs (e.g. birds monitoring society), we know that such organisations are regularly collecting data, but we did not find that information online.

Filling the table

For most data from the national sources, we were not sure if there is any official name for the data. So, we wrote a name that indicates the purpose of the data (e.g. forest management data, nature conservation data). In the case of the central forestry database, we referred to groups of data as being products (e.g. NFI, forest management data, forest health data). The database serves as a basis for creation of different types of maps. As several maps based on these data were found (the geoportals of public forestry enterprises), we entered them in the table as individual products, indicating the relation to the database (in the column 'Sensor or data base'), and for the 'data name' we used the name that indicates the purpose of the data (e.g. forest management data).

Some data, as in the NFI case, are based on a systematic sample in the form of clusters distributed in a grid. For that case, we were not sure what to choose as a spatial resolution (e.g. the level of a sample plot or of a grid square), so we provided all sizes - for a grid square, cluster and sample plots. Also, the size of a sampling grid may vary depending on the type of data (e.g. in the NFI, for LULUC data 1x1km, while for the forest plots a 4x4km grid is used). This was noted in the column on spatial resolution.

In the column 'Frequency of data acquisition', we were not sure how to insert information on data types as e.g. protected areas or forest management boundaries. We entered 'periodical' only to indicate that those data are prone to changes, but which do not happen that often. In the column 'Year', only for PA, it was indicated that the years of PA establishment vary.

In the case of the column 'Description / classes of land use / forest', if the data related to forest types, only the number of classes was entered. We felt that writing in all the possible classes was not feasible and not very useful, because these are defined within the national frame. This also accounts for PA categories which are not equal to the IUCN categorisation. In the column 'Used land use / forest definition', we indicated that the national definition is used, or something else. Moreover, there are different classifications of forest types and this was also noted on which classification forest types are based. FAO forest definition would apply for all forest-related data as underlying definition.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1): The forestry information system collects data that can be related to all ecosystem services categories (provision, regulation, cultural). The amount of data stored and its quality is not fully visible though, mainly if considering forest management data, which is of higher importance at lower spatial levels. The amount of information stored in the database has been increasing in terms of aspects that were not considered in the past (e.g. biodiversity related data), but the amount of data related to such new aspects and the time span covered is questionable. The data is updated every 10 years, and the time of update varies across forest management units, so the information covered may not be the same for all forests. This is something that could be checked, since the period covered by management plans can be checked. The update frequency (10 years) could be a limitation for some ES cases. Also, the longest period for the availability of spatial data is probably up to 20 years, with the quality increasing over the time. Therefore, the database could be limited with respect to some ES categories or sub-categories, as for example NTFPs, habitat, climate regulation or some other. Some of these aspects could be covered through other information sources, e.g. nature conservation organisations, but from these sources it was more difficult to screen what is available. The most accentuated/visible data is on protected areas distribution and categories. The national ecological network that involves sites of conservation importance is not available online. All of the data found is mainly fieldwork data, which raises its accuracy, but the coverage could be limited. Limitations are also expected when

it comes to some ES categories (e.g. regulating), as data harder to measure may be necessitated, which is not covered by data bases of public organisations. That kind of data is expected to be found in the academic sector, but our search gave only few results. Products based on remote sensing data are much less represented.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text): Currently, the main limitation in Serbian case is the data accessibility. Even though this should be public data (state-owned forests), it is not clear what data and under what conditions they can be used. Also, because the data itself is not visible, it is difficult to judge the quality and hard to identify potential gaps. We can only assume that many ES categories could be covered, given the amount of information collected for forests in Serbia. Considering that, we would also expect to find more products in the form of different maps, so this is something that could be improved. Inclusion of remote sensing data in creation of such products is recommended, as it offers more opportunities. So far, the use of this type of data is poorly represented.

14. Country Report: Slovakia

Author(s) of this report + institutional affiliation(s):

- Martina Štěrbová, National Forest Centre, T. G. Masaryka 2175/22, 960 01 Zvolen, Slovakia
- Yvonne Brodrechtová, Ján Tuček, Róbert Sedmák, Technical University of Zvolen, Faculty of Forestry, T. G. Masaryka 24, 960 01 Zvolen, Slovakia

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

The main source of information about forests is the Forestry Information System (**see Table 1, No. 1.1 and 1.2**), which is operated on the basis of Act on Forests no. 326/2005 Coll. Based on § 38 and §45 of this act, its administrator is the National Forestry Center located in Zvolen Slovakia. The sources of forestry information system are following:

- forest management plans: data concerning (1) description of stands, (2) management actions plan, (3) state of forests (complex assessment), (4) area table, and (5) forestry maps,
- forest management evidence: data concerning economic measures taken in stands (e.g., logging, afforestation, planting measures, education) (the evidence is maintained the state forest administration),
- registers of forest land according to forest managers and professional forest managers (the register is maintained by the state forest administration),
- registers of forest managers, professional forest managers, forest guards, cups, register of qualified persons for activities with forest reproductive material (the register is maintained by the state forest administration and Ministry of Agriculture and Rural Development of the Slovak Republic),
- statistical surveys in the field of forestry, hunting and primary wood processing.

The information on forestry, hunting and wood processors for individual years is available via application: Information bank of data on forestry, wood processors and hunting (**Table 1, No. 2**) (application maintained by the National Forest Centre Zvolen). It is one of the important sources for Report on Forest Management in Slovak Republic (basic document on state of forests, timber trade among others), available online by the Ministry of Agriculture and Rural Development of the Slovak Republic (**Table 1, No. 2.1**). Due to ongoing climate change and its impacts, an information visualizing actual and historical satellite compositions of Slovak territory started to be offered online in order to allow users, for instance to monitor forest stands (**Table 1, No. 3**) (web side maintained by the National Forest Centre Zvolen). Another source of information on forests in Slovakia carried out by the National Forest Centre in Zvolen is National Forest Inventory (NFI) from 2005-2006 and from 2015-2016 (**see Table 1, No. 4**).

Geoportal web maintained by Geodetic and Cartographic Institute Bratislava provides reference spatial data, spatial data services and information about spatial reference data according to acts no. 215/1995 Coll. and no. 168/1995 Coll. in the following areas: Cadastre of Real Estate (T**able 1, No. 5**), Geodetic Control, Basic Data Base for the Geographic Information System ZB*GIS*® (**Table 1, No. 6**) and State Map Series (**Table 1, No. 7, 8, 9**). The main source of forestry related information is Cadastre of Real Estate (**see Table 1, No. 5**), which is operated according to the National Council of the Slovak Republic Act on Geodesy and Cartography no. 215/1995 Coll. and Act on Real Estate Cadastre and Registering of Ownership and Other Rights to Real Estates no. 162/1995 Coll. (Cadastral Act). Cadastral documentation is kept in paper or electronic form. Basic data base for the geographic information system (ZB*GIS*®) (**see Table 1, No 6**) is part of the Information System of Geodesy, Cartography and Cadastre, which has been created and maintained by the Geodesy Cartography and Cadastre Authority of the Slovak Republic under the Act on Geodesy and Cartography No. 215/1995 Coll. Scope of data on features managed within ZB*GIS*® is specified by Feature Catalogue (KTO ZBGIS®). Visualization of ZBGIS® data through map compositions is available via MAPKA application. A new product - ZBGIS® Raster is available to public since 2018. Downloading ZBGIS® rasters is possible via the MAPKA application.

Conclusion: In total, 11 data sets were identified on national level for Slovakia. The majority of datasets are based on two large sources of information: Forestry Information System and Geodesy and Cartography and Cadastre Authority of the Slovak Republic. The data sets have mainly annual updates. However, FMP or NFI are updated every 10 years. Moreover, the data in Cadastre are updated monthly. The oldest source of data could be considers FMP. The bulk of datasets on forestry is restricted to public (mainly

primarily datasets in comparison to secondary). In contrast, information sourced in Cadastre Authority of the Slovak Republic is available to the public.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

- Generally, quality of data in Slovakia is high.
- Commonly, results from FMPs are used for national reporting due to the long history and to ensure continuity. Lately, also NFI results (e.g., deadwood, forests on non-forest land) have been used for reporting purposes at national and regional level. As a result, NFI data are used predominantly for scientific purposes. One of the reasons is that the results show high differences between statistics made from FMP and NFI, especially in relation to growing stock.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

- Generally, data quality and accuracy is in the norm, however, there is always room for improvement (which usually depends on available financial resources and political will). Similarly to other countries, the usage of data could improve when data collection methods, data types among others would be in a comparable format (e.g., international reporting).

15. Country Report: Slovenia

Author(s) of this report + institutional affiliation(s): Andrej Bončina, University of Ljubljana, Biotechnical Faculty, Department of Forestry and renewable forest resources

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

There is a lot of dataset available on forests. Slovenia Forest Service is the main provider of data, followed by Slovenia Forest Institute and several public institutions responsible for phenomena in forest area (e.g. nature conservation, gravitational hazards, water streams, ownerships). Probably, creating lists and definitions of various spatial data for our Cost action is not a main objective or at least it should not be. Therefore, I mentioned only four main spatially explicit inventory units (i.e. a stand, permanent sampling plot, forest function area, compartment). Data from these units can be applied at different spatial scales, combined with other (non-forestry) sources of data, and applied for creating numerous different spatial units.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Quality of data is improving. The challenge is, for instance, developing application for automatize stand mapping, improving methodology for mapping forest ecosystem services functions), integrating remote sensing techniques to improve data quality and increase control on forests and forest management. A transition to modern field (digital calipers, digital vertexes, drones, monoculars...) and office equipment (powerful computers, servers and software) should be implemented in combination with an upgraded spatial information system to provide support for the most demanding spatial analyses, planning and implementation of forest management with the main task of simplification, optimization and upgrade. For forest owners and other stakeholders, this will lead to a more efficient and streamlined service, enhanced by increased data availability, reduced bureaucracy, and quicker, clearer access to information regarding forest and forest management. The installation of the new application will provide forest owners and managers with enhanced insights into the history of forest development and management, along with tools that facilitate participatory decision-making.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

No recommendation.

16. Country Report: Spain

Author(s) of this report + institutional affiliation(s): Fernando Pérez-Rodríguez, fora forest technologies SLL

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

Currently, there are too many data sources available (open access). Much of them was acquired by field measures, but there are many data sources resulted on simulated or correlated with remote sensing.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

The frequency of acquisition in many specific data like forest inventories could be not enough to get the reality of areas with quick growth like Eucalyptus sp. For example, a national forest inventory with 10 years' frequency is over the turn of final cut in Eucalyptus globulus in the north of Spain. However, the 6 days' frequency of Sentinel-2 could be used, but it has other issues like is not properly forest information, only multispectral, and all the products generated are correlations with field measurements with the problem of accuracy.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

A big consideration to use the data when remote sensing is used in combination with national forest inventory is that the coordinates of the forest plots need to be revised.

17. Country Report: Sweden

Author(s) of this report + institutional affiliation(s): Jacob Parry (SLU), Ruben Valbuena (SLU)

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Short conclusions on the documentation of the spatial data / data bases from your country for DSS4ES (please write a text here and refer to Table 1):

National Forest Inventory data is publicly available in Sweden in the form of various forest variables. These are typically split on a regional basis, i.e., forest area for different species and age classes in different regions. It may be that a Site Index table and a map (the key input for Heureka DSS) is available, but this is unclear. NFI data is available in csv/numerical format. Raster maps are also available of key forest attributes. A detailed land cover map of Sweden has also been created showing land use and classes.

Data gaps / data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

- The Forest Base Maps does represent the given scanning date, meaning areas close to each other could differ in time.
- The Land cover data is based on a mixture of LIDAR data and satellite images, all coming from different years. But it's more updated regarding clear-cuts.
- The detected clear-cuts data should be used with caution. The clear-cut date gives a rough idea when it was clear-cut. The actual time interval could be within 1-2 years.

Recommendations to improve the data base in the frame of DSS4ES (general or country-specific but please specify in your text):

Some work has been done to develop a site index map of Sweden for different species: https://www.mistradigitalforest.se/en/news/site-index-based-on-data-from-laser-scanning-provides-maps-with-great-potential/. This is vital for input into DSS. SLU can do some work to track this down and see if it can be made available.

18. Country Report: Turkey / Türkiye

Author(s) of this report + institutional affiliation(s):

- Fatih SİVRİKAYA, Kastamonu University
- Alkan GÜNLÜ, Çankırı Karatekin University
- Derya Mumcu KÜÇÜKER, Karadeniz Technical University
- Sinan BULUT, Çankırı Karatekin University
- Zennure UÇAR, İzmir Katip Çelebi University
- Hasan AKSOY, Sinop University
- Enes CENGİZ, Sinop University
- Mehtap Koç, Istanbul University-Cerrahpasa
- SELIM BAYRAKTAR, Istanbul University-Cerrahpasa

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Short conclusions on the documentation of the spatial data/databases from your country for DSS4ES (please write a text here and refer to Table 1):

Currently, there are many data sources available (depending on permission). Many of them were obtained by field survey, but these traditional field surveys integrate with remote sensing data. This combined method is used for determining the ecosystem services. The data come from both ground measurements and remote sensing, processes with geographic information system.

Data gaps/data problems especially for which categories, spatial levels, time spans, ecosystem services, etc. from your country (please write a text here and refer to Table 1):

Forest cover type maps and ground survey data (all together forest inventory data) are obtained with 10-20 years' interval in Türkiye. The database maintained with GIS is managed by state forest service (GDF – OGM). Thus, permission is required for the use of all available data. On the other hand, Global world cover map with 10 m cell size can be used as another data source in determining the ecosystem services.

Problems:

- Site productivity data is purely dependent on dominant trees, not exactly on soil and geological characteristic.
- Forests inventory data may not be updated regularly depending on the technical persons and budged as well as forest administrational policy.

There is a notable lack of spatially detailed data at the regional and local levels, which can impede targeted interventions and localized assessments of ecosystem services. Even geological and soil maps at a 1:25,000 scale have only recently been completed, highlighting the significant need for local data. Furthermore, accessing higher-scale data often requires navigating extensive bureaucratic processes, which can delay data availability.
Data collection efforts often lack engagement with local communities and stakeholders. This can result in gaps in understanding local ecological knowledge and the socio-economic factors influencing land use decisions. Current data tends to focus more on forest cover and timber production, with insufficient attention given to biodiversity conservation and the social dimensions of ecosystem services. Integrating more diverse indicators, such as community well-being and cultural values, would provide a more holistic view of ecosystem service dynamics.

Recommendations to improve the database in the frame of DSS4ES (general or country-specific but please specify in your text):

Many valuable datasets currently lack digital access. Establishing a centralized online portal where all spatial data can be easily accessed and downloaded will facilitate broader usage by researchers, policymakers, and stakeholders. Expanding the database to include socio-economic data, land use change, and community-based forestry information will enrich the analysis of ecosystem services.

Data sources prepared for Türkiye by the General Directorate of Forestry provide information about forest ecosystem services, including sustainable wood production and other ecosystem services (recreation, protection and conservation (hydrology, soils, biodiversity, etc.). In this context, large coverage data particularly from other related disciplines is needed to accurately determine other ecosystem services (such as biodiversity conservation, recreation, ecotourism, soil conservation, water production, landscape appreciation, etc.).