ForestNavigator

D4.2 Report on socioeconomic variables

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Abstract

This report presents the collection of socioeconomic indicators to be tested in T4.3 and T4.4 analyses and modelling to assess employment opportunity, profitability of wood provisioning, and monetary values for recreational and cultural services. The list is selected based on existing studies and the models used in ForestNavigator. These indicators are categorized according to the main societal or economic aspects they cover. Attention is given to describing the planned use of each indicator, including spatial and temporal resolution, data sources, as well as adaptation needs to make the indicators operational within the modelling framework.

Keywords

Socioeconomic indicators, benefit transfer, monetization, forest ecosystem services

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Table of Contents

List of Figures

List of Tables

Abbreviations

CPI	Consumer Price Index
GDP	Gross Domestic Product
GVA	Gross Value Added
ILO	International Labor Organization
LCU	Local Currency Units
LFS	Labor Force Survey
NACE	European statistical classification of economic activities
NUTS	Nomenclature of Territorial Units for Statistics (Level 2 = basic regions for the application of regional policies in a country)
PPP	Purchasing Power Parity
PPS	Purchasing Power Standard
SEEA EA	System of Environmental Economic Accounting Ecosystem Accounting
T	Task
WP	Work Package

1. Introduction

The ForestNavigator project develops a series of policy pathways aimed at achieving climate neutrality for the EU and its member states. These pathways must account for the effects of forest management decisions on ecosystem services. As defined by the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA), these services encompass the contributions of forest ecosystems to the benefits utilized in economic and other human activities (UN 2021).

Within the project's Work Package (WP) 3, methods are developed to improve the representation of forest biophysical attributes under the influence of climate change and to assess various management options for progressing towards climate targets. Complimentarily, WP4 leverages these biophysical representations to evaluate their influence on ecosystem services and related supply and demand dynamics. Central to this assessment is the integration of biophysical and socioeconomic inputs, facilitating the spatial analysis of the profitability of wood provisioning profitability and related employment opportunities (Task 4.3) and the monetary evaluation of cultural services, including recreation[i] (Task 4.4).

Homogenous, spatially explicit, and timely data regarding forest management profitability and the monetary values of forest ecosystems are lacking in the EU. For specific geographic points or regions this information is available. Spatializing/extrapolating from one point, where the information is available, to another requires combining the underlying forest structures variability with socioeconomic indicators combined in benefit transfer approaches (Di Fulvio et al. (2016), Kerry Smith (2018), UN (2021), Elsasser et al. (2021), Grammatikopoulou et al. (2023)). These indicators, retrievable from existing EU-wide openly accessible collections of socioeconomic indicators, are typically compiled at the administrative region (NUTS2 /Country). Tasks 4.3 and 4.4 combined incorporate these indicators into a suitable modelling framework, which allows for the extrapolation of the effect of socioeconomic conditions, i.e. gap-fill missing information, and estimate monetary values across entire regions.

This report presents the collection of socioeconomic indicators identified to be tested in T4.3 and T4.4 analyses and modelling. In Chapter 2, we describe the selection of indicators collected, based on existing studies and the suite of models used in ForestNavigator. In Chapter 3, indicators are categorized according to the main societal or economic aspects they cover. Attention is given to describing the planned use of each indicator, including spatial and temporal resolution, data sources, as well as adaptation needs to make the indicators operational within the modelling framework. In Chapter 4, we describe the next steps needed for adapting the collected indicators to the specific modelling needs under T4.3 and T.4.4.

[i] Despite notable advancements in the classification of ecosystem services, an internationally agreed-upon classification remains pending. Therefore, within the context of WP4 and this report, we adopted the list developed by SEEA EA. On top of the most known and estimated forest ecosystem services (e.g., provisioning, regulating and maintenance) we adopt the definition of SEEA EA for cultural services, which broadly group them into i) recreation-related services, ii) visual amenity services, iii) education, scientific and research services, iv) spiritual, artistic and symbolic services, and v) other cultural services.

2. Methods

Forest management is the main tool for controlling structures by changes in tree species, trees sizes, densities, sizes, and shapes of cutting/regeneration areas. All these structural attributes control the profitability of wood provisioning, as well as (visual) perception and usability of forests for cultural services[ii].

Tasks 4.3 and 4.4 improve the comprehension of the profitability for the wood provisioning ecosystem service as a function of forest management decisions, as well as the value of cultural ecosystem services provided by forests. The process of translating the values associated with forest management alternatives into monetary terms requires the simultaneous consideration of three factors: the potential changes resulting from modifications in forest structural variables, the socioeconomic context that influences forest products and services demand and supply, and the attitudes of forest owners and users towards active interventions in forest environments. Therefore, to accurately model the value of ecosystem services over entire EU regions, it is essential to grasp the nuanced spatial variations in socioeconomic conditions. This Chapter presents a collection of socioeconomic indicators aimed to enhance the understanding of this variability.

Selection of indicators

The selection of socioeconomic indicators for modeling in Task 4.3 and 4.4 adhered to the following criteria to ensure suitability and relevance:

- **Literature-informed selection:** Indicators were informed by existing literature where relevant relationships between socio-economic variables and ecosystem services outcome have been observed.
- **Geographic coverage:** Emphasis was placed on indicators covering most of the EU region, and ideally encompassing the entire EU area.
- **Spatial detail:** Indicators were chosen to provide spatial granularity (Country/NUTS2 resolution), allowing for reference to specific regions or countries within the EU.
- **Temporal scale** Priority was given to indicators regularly updated, ideally on an annual basis, and available for a recent point in time.

Priority for data sourcing has been given to EU-wide statistical collections (i.e. EUROSTAT), accessed during the period 2023/2024. Indicators not available from EUROSTAT or not provided at the required level of detail were retrieved from other sources, including global databases (the World Bank, International Labour Organization) or national statistical offices collections.

The selection of socioeconomic indicators for the spatialization vary on their intended application. Both demand- and supply-oriented indicators are considered. On the one hand, the spatialization of recreational and cultural values (T4.4) requires a comprehensive understanding of societal and economic conditions. This includes considering the needs, preferences, or demands of various stakeholders or users (individuals, communities, industries, or organizations) of forest resources

[ii] According to SEEA EA, visual amenity services are the ecosystem contributions to local living conditions, through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual. According to SEEA EA, recreation-related services are the ecosystem contributions, through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment.

and services. On the other hand, evaluating the profitability of management options from the perspective of wood provisioning requires a more detailed understanding of specific economic indicators that influence the costing of timber supply (T4.3).

Cultural values are estimated at the level of country for the pilot cases of Sweden, Italy, Ireland, and Czechia. Furthermore, the spatialization of these country-based results to the whole of Europe is conducted according to administrative regions, i.e. NUTS2 (T4.4). Under T4.3, we combine structural forest variables (5 arcmin resolution) with socioeconomic variability (NUTS2/country) to obtain a gridded assessment (5 arcmin resolution) of wood provisioning profitability. Complementary, we will assess employment opportunities by employing a more aggregated assessment at the resolution of administrative regions (NUTS2).

Time period

For most indicators time series were created spanning the years 2015 to 2023, depending on data availability.

To ensure accurate comparisons of economic variables across different time periods, we collected data on the Consumer Price Index (CPI) for the economic evaluations. This enables a more precise representation of real economic values adjusted for changes in purchasing power over time.

The COVID-19 pandemic has had significant impacts on major macroeconomic variables fluctuations between 2019-2021. Abrupt shocks and structural breaks have disrupted economic activity, leading to sharp contractions in output, employment, and demand across many sectors. The pandemic-related policy responses have further exacerbated the distortion of trends or patterns over time, causing data from this period to diverge from historical patterns or relationships. The degree of divergence can vary depending on the sensitivity of each indicator. For this reason, to ensure robustness of our evaluations and to enhance reliability of our analyses, we include a range of similar indicators capturing the same economic phenomena but with several dimensions. The consideration and use of potentially substitute indicators provides a more comprehensive and nuanced understanding of economic phenomena and facilitates comparative analysis, validation, benchmarking, and better-informed decisions and policies. In a later stage, whenever it is considered that complementary indicators are redundant, depending on data availability, quality, and data potential limitations across regions, we may choose the best dimension to use amongst the diversified sources.

Spatializing variables using a benefit transfer approach

In T4.3 and T4.4 we will employ “benefit transfer” approaches to transfer information associated with environmental resources or ecosystem services acquired from specific sites. Following Rosenberger & Loomis (2001) these methods involve adapting and utilizing “economic information derived from a specific site(s) under certain resource and policy conditions to a site with similar resources and conditions”. This approach is a valid strategy to evaluate management and policy impacts in situations where primary research, which should be the ‘first-best’ strategy, is not feasible due to budget limitations or time constraints.

Several approaches can be used for benefit transfer analysis. They span from Unit Value Transfer or single point estimate transfer, Meta-Analysis, to benefit transfer functions, etc. (Adamowicz et al 1994; Rosemberger & Loomis 2001; Freeman 2003; Grammatikopoulou et al. 2023). T4.3 will rely

mostly on transfer of single points estimates whereas T4.4 will combine multiple approaches, including benefit transfer functions.

The specific relation between the observed values and each socioeconomic indicator will be adjusted according to what is observed in the literature and what will result from the ongoing complementary analyses (e.g., the choice experiment study in T4.4). These results will also drive the choice of the relational equations for the benefit transfer approach.

Even if we aim to have indicators able to cover the entire EU, some of them are not available for all countries/regions. In this case, we will use regional averages as a remedy for missing observations, as a tool for gap-filling spatial information.

The integration of the socioeconomic and biophysical domains in our approach will be made feasible through the utilization of a suitable modeling framework, which is based on the IIASA forest models. G4M and GLOBIOM serve as the foundational modeling frameworks upon which we rely to facilitate the derivation and analysis of the spatial distribution of monetary values associated with forests. Specifically, the development of a new forest model (G4M-X) will enhance our ability to project future variability in the structural forest attributes across space and time. This variability will be coupled to the spatialization of socioeconomic drivers, which will be herein described and represented by the collected indicators.

3. Socioeconomic indicators

This Chapter outlines the socioeconomic indicators selected according to sub-sections: 1) Macroeconomy, 2) Labor market, leisure time balance and attitudes 3) Population and social composition 4) Governance and institutional arrangements, and 5) Forest accessibility, infrastructures, and accommodation facilities.

The categories are briefly described, motivated, and contextualized within the existing literature. *Table 2* in the Annex lists all the indicators, providing a complete overview of their source, temporal and geographical scope/availability, as well as use in the project Tasks.

3.1. Macroeconomy

Macroeconomic indicators are statistical measures that provide insight into the overall performance and health of an economy at a national or regional level. In the context of our analysis, they describe various aspects of economic activity, including production, employment, prices, and growth of the region or areas where forests are located.

Macroeconomic indicators can provide valuable insights into the economic significance, impacts, and trade-offs associated with forest management and conservation decisions, also leading to implications for ecosystem services. Their use can help integrate economic considerations into forest management strategies and decision-making processes promoting the sustainable management of forest resources.

Changes in macroeconomic indicators can signal shifts in the demand for and supply of ecosystem services. They reflect broader economic trends and dynamics, including globalization, trade patterns, and market integration. For example, fluctuations in GDP growth rates or unemployment levels may indicate changes in economic conditions that affect the demand for timber products, expansion of international markets for non-timber forest products, or impacts on forest-based livelihoods, recreational opportunities, or carbon sequestration services provided by forests.

Relevant macroeconomic indicators potentially needed for our analyses (T4.3, T4.4) are reported in Table A.1. The final choice will be driven by specific modeling needs, some of which will be clarified in later stages.

Gross Domestic Product (GDP) in per capita levels represents the economic development of a region. It reflects the total value of all goods and services produced minus the value of goods and services used for intermediate consumption in their production. The calculations on a per inhabitant basis allow for the comparison of economies and regions that are significantly different in absolute size. This indicator is generally considered representative of socio-economic wellbeing and has been positively correlated to the monetary value of ecosystem services assigned to forests (Grammatikopoulou & Vačkářová 2021, Chiabai et al. 2011). GDP adjusted by Purchase Power Parity (PPP), is usually preferred for removing the effect of exchange rates (price levels between countries). The availability of this indicator at the level of NUTS2 offers the possibility to perform adaptations also within each country according to differences in single administrative regions.

Projections of future GDP development according to SSPs (Shared Socioeconomic Pathways) scenarios at country level (up to the year 2100) are retrievable from the IIASA SSP database

(https://data.ece.iiasa.ac.at/ssp/#/workspaces). Gridded GDP at 5 arcmin resolution, with past observations (1850-2000) harmonized with future projections according to the Shared Socioeconomic Pathways (2010-2100) are provided by Geiger et al. (2017)

For comparison of non-traded locally purchased goods and services, there is a need to use synthetic indicators that make it possible to compare the cost of a common bundle of goods across countries, independently from the exchange rate. This comparison is performed by means of a **Purchase Level Ratio** based on the PPP that is collected at the country resolution. It is the ratio of a purchasing power parity (PPP) conversion factor to an exchange rate. It provides a measure of the differences in price levels between countries by indicating the number of units of the common currency needed to buy the same volume in each country. For evaluating the costs of capital investments in forest operations in a certain region (planting a new forest, purchasing forest equipment), along with forest ecosystem structure and endowment, some general information on the risk and return from investments are needed, this would serve for evaluating the competitiveness compared to other forms of investments. To this aim, **interest rates** reflect the returns on financial investment, and can be used also for discounting future returns from capital investments according to countries' borders. The interest rate expresses the amount a lender charges a borrower, and it is a percentage of the principal amount loaned. The interest rate on a loan is typically noted on an annual basis and expressed as an annual percentage rate. Exchange rate volatility can reflect uncertainty and barriers to market integration: exchange rate fluctuations affect the prices of imported and exported goods, influencing trade flows and market integration, then, they can also function as a proxy for integration. These rates can be combined in more complex indicators like the Risk Adjusted Discount Rates, that can be applied for evaluation of investments as in Benitez et al (2007).

A **Consumer Price Index** (CPI) can be used as a multiplier for making possible a comparison of monetary values collected over time, by accounting for the effects of inflation on the value of currencies. Specifically, for EU countries, the HCPI (harmonized Consumer Price Index) can be applied to cost/price and inflate/deflate for comparisons to other prices/costs (allowing for a standardization to same reference year).

The collection of monetary costs in different countries happens often in local currencies (LCU), and this is the case also in many EU countries where local currencies are still used. A standardization to a common currency (EUR) can be obtained by means of **official exchange rates** that can be retrieved from the EU central bank. These are the price or value of one country's currency in relation to another.

Profitability (P) of wood provisioning is calculated as the difference between revenues (R) from selling wood and cost (C) for management and wood supply.

$$P(x) = \sum R(x) - \sum C(x)$$

$$R(x)_j = p(x)_j * q(x)$$

$$C(x)_j = FC + c(x)_j * q(x)$$

Wood selling revenues from forestry are relevant for computation of profitability of alternative management options. Revenues from wood are the combination of amount of wood delivered to the market (q), which can be modelled according to the EU forest model (G4M) calibrated to historical production statistics (FAOSTAT) and **wood prices** (p) in a country (j). The calibration to

historical price of wood is available only for a subset of eight EU countries (France, Finland, Slovenia, Sweden, Lithuania, Austria, Czech Republic, Poland), where time series can be retrieved from the UNECE until year 2019. These prices need to be treated carefully, distinguishing assortments (sawlogs, pulpwood, fuelwood), their point of evaluation along the wood supply chain (roadside, industry), as well as standardized to a common currency, given that are collected in local currencies. Updating the wood prices after the calibration, based on the available ones (until year 2019), will be based on solving the market equilibrium in the GLOBIOM model. Price differentials between markets can reflect transportation costs, trade barriers, and market segmentation. The convergence of prices for identical or similar goods and services across different markets/regions can be also considered an indicator of integration and arbitrage opportunities.

Production costs depend on fixed costs (FC), i.e. independent of quantity of wood harvested and/or produced, and variable harvesting costs (c), that depend on wood harvest and/or production levels (q). Among variable costs, the most relevant are labor costs and fuel costs.

The latter costs represent a large driver of forest management and wood harvesting costs (Di Fulvio et al. 2017). This is particularly the case of EU, where most of forest harvesting operations can be mechanized (Pucher et al. 2023). A cross country border adaptation of fuel costs will rely on their consumption (liter/hour) in forest operations and **fuel prices** (EUR/liter) that vary according to country border (j).

$$\text{Fuel Cost operation}_j\,(\text{EUR}) = \text{Fuel price}_j\,(\text{EUR/liter}) \times \text{Fuel consumption (liter/hour)}$$

Conventionally, fuel prices paid by forestry enterprises are under reduced taxation, therefore, adjustment across country borders should account of net fuel prices, VAT, excise and duties and other indirect costs. This requires consulting databases where the fuel pump price is decomposed accordingly. EUROSTAT presents up to date collections of diesel and gasoline pump prices for all EU countries, differentiating the taxation level applied in each EU country.

3.2. Labor market, leisure time balance and attitudes

The labor market provides important information on the socioeconomic context for understanding the drivers and consequences of changes in forest ecosystem services. For instance, income inequality, poverty levels, work-life balance, employment trends can influence the demand for ecosystem services and the distribution of benefits and costs associated with forest management decisions.

Regional **employment/unemployment** is a key indicator for further understanding the societal conditions in a region. Overall employment statistics are available at the spatial resolution of NUTS2, as an aggregate over economic sectors with a split according to sex and age. At the same resolution there is availability of regional unemployment statistics, as percentage of the economically active population.

Forestry activities still require relevant input from forest labor, for operating forest machinery, planning of operations and supervising of them. Forest industry is also offering employment in production of semi-finished wood products and final products. For this sector, there are statistical collections derived from the Labor Force Survey conducted at country level that are accessible through ILOSTAT and EUROSTAT and updated to year 2022.

According to the NACE[iii] rev. 2 classification, forestry, and wood-based value chains (including primary processing of wood products) map to the following reporting categories:

- Forestry, logging, and related service activities (A02)
- Manufacture of wood products and products of wood and cork (C16)
- Manufacture of paper and paper products (C17)

We have excluded wood-based secondary processing and manufacturing identified by Robert et al. (2020) (C31 Manufacture of wood-based furniture, C18 printing and reproduction of recorded media, C35 Electricity, gas, steam and air conditioning supply, J58 publishing activities), given the involvement of activities linked to final processing/consumption of wood commodities that are not covered in T4.3 modelling.

Employment in forestry and logging activities (A02) is relevant data for calibrating the labor demand across different regions and for further modelling labor needs in forest operations after an historical calibration to the available time series (Toth et al. 2019). The EUROSTAT collection offers possibility for calibrating employment in this sector according to the observed statistics that cover last 10 years (Fig.2).

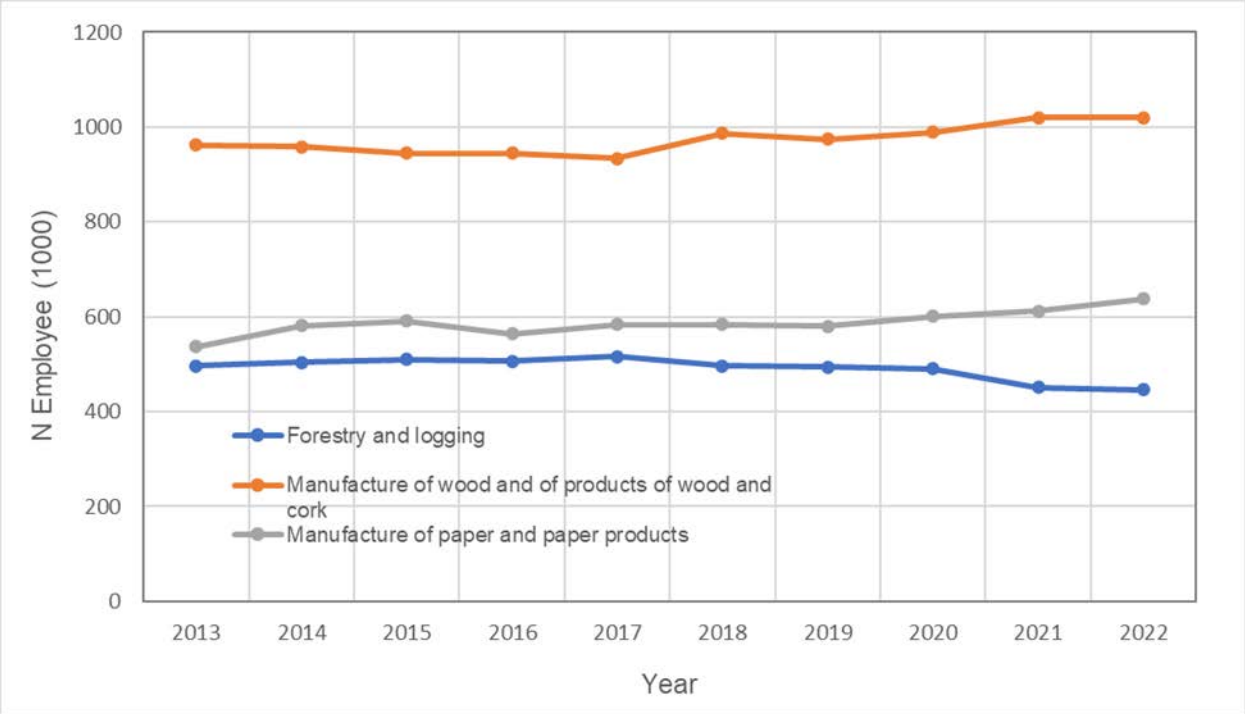

Figure 1. Number of employees ('1000) in forestry and primary wood processing over time for the EU27. Source: EUROSTAT.

Together with employment statistics, the **cost of labor** (EUR/hour) is another critical variable that defines the cost of management systems. By multiplying the working time for performing a certain operation by the hourly remuneration of the workforce in a country (j), it will be possible to assess the overall cost of operations.

[iii] Statistical classification of economic activities in the European Community. https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-ra-07-015

Labor cost operation (EUR)$_j$ = Hourly Labor Cost $_j$ (EUR/Hour) x Working Time (Hour);

The **earnings** of employees relate to the gross remuneration in cash and in kind paid to employees, as a rule at regular intervals, for time worked or work done together with remuneration for time not worked, such as annual vacation, other type of paid leave or holidays. Earnings exclude 'employers' contributions in respect of their employees paid to social security and pension schemes and also the benefits received by employees under these schemes. Earnings also exclude severance and termination pay.

Earnings per hour (LCU/month) are collected by ILOSTAT, in the case of forestry, the sector is merged with agriculture and fisheries and statistics are available at country level. There are different categories of workers being employed in forestry, that influences their level of wage. However, statistical collections differentiating according to level of qualifications are not available for each specific sector. Earnings collected in statistical databases are net of social charges and taxation that needs to be added for calculating the gross remuneration of forest employees.

Taxation on labor varies according to national agreements and regulations, hence, such information becomes relevant when adapting labor costs to country borders. A collection of taxes and contribution rates, as a percentage of business profitability, is available from the Word Bank Doing Business database and it can be used for inferring impacts of taxation on labor cost.

Working time, as hours per year spent on remunerated work activities, can complement the employment and unemployment rates. It is a useful indicator for further translating number of employees into scheduled work time, that is the variable output of common modelling of forest operations. The work time is based on the LFS and available per country and NACE sector with a split of forest sector as for the employment in EUROSTAT and ILOSTAT.

Individuals with a **balanced leisure time** may find less challenging to have sufficient time, flexibility, and opportunity to engage in forest cultural and recreational activities more frequently, eventually exploring more diverse activities, and better enjoying the benefits of spending time in nature, having higher quality of experience. EUROSTAT provides an indicator based on leisure time balance satisfaction for the year 2018, while OECD offers information on the time use, i.e., the time spent in unpaid work and leisure, for different years. Ultimately, 'Our World in Data' provides an overview of the gender disparity in leisure time among individuals aged 15-65.

Attitudes towards conserving natural resources encourage people to promote sustainable practices, preserve forested areas and maintain their ecological integrity. This preservation ensures the availability of suitable habitats for wildlife and diverse plant species, enhancing the biodiversity of forests. In turn, biodiverse forests provide more opportunities for cultural and recreational activities such as birdwatching, wildlife photography, and nature walks. The Eurobarometer Survey explores European respondents' perceptions, awareness of and views on biodiversity and nature and provides information on the perceived 'importance of nature protection areas and of attitudes to developments that may damage these areas'.

3.3. Population and social composition

The demand for forest ecosystem services derives from the perceived utility gained from their use (socio-economic indicators) as well as the relative abundance or scarcity of ecosystem services in a certain area (bio-physical indicators). Ecosystem services vary largely in terms of their characteristics and benefits delivered to society. In this section we mostly focus on the cultural and

recreational services, that are more directly influenced by the characteristics of the societal structure (population and population density, age, education, income distribution, etc.).

Population density (along with distance from forest ecosystems) has been suggested to have a significant effect on the demand for cultural and recreational forest services (Quintano & Barredo 2015, Pisani et al. 2022). As for the overall population, also the density is available at the NUTS2 resolution from EUROSTAT, allowing for regional adaptations within a country.

Regional **Population** can be used for upscaling the value of ecosystem services from samples (e.g. interviewed population) to an entire geographical region, as higher number of local inhabitants may translate into more people demanding for forests in neighboring areas for recreational activities (Elsasser et al. 2021). Regional population statistics at the NUTS2 level are available from EUROSTAT and are yearly updated. Projection of future population according to SSPs at country level (up to the year 2100) are retrievable from the IIASA SSP database (https://data.ece.iiasa.ac.at/ssp/#/workspaces). Downscaled historical (2000) and projected (2000-2100) gridded population densities at the resolution of 7.5 arc min are globally available from Jones & O'Neill (2016).

The **Societal structure** can affect the demand of recreational services in various ways (e.g., Nielsen et al., 2007, Semmens et al. 2019, Tuffery 2019, Wiernik et al., 2013, Elsasser et al. 2021). The information on the categories highlighted below is derived by combining available statistics from EUROSTAT.

- **Age and gender structure**: different age groups and gender often have distinct preferences and needs when it comes to recreational activities. For example, younger individuals might be more inclined towards adventurous activities like hiking and rock climbing, while older individuals might prefer more leisurely activities such as birdwatching or nature walks. The indicator refers to population classified according to age classes of 1 year and by sex at NUTS2.
- **Level of education**: individuals with higher levels of education may have greater awareness and understanding of the benefits of spending time in natural environments and forests. Education can foster an appreciation for nature and the outdoors and increase preference for healthier lifestyles. The indicator refers to population per country according to ISCED 2011[iv] classification.
- **Urbanization:** urbanization can increase the demand for recreational opportunities nearby forested areas as people seek respite from urban environments. This indicator classifies country population by degree of urbanization distinguishing according to three categories (cities, towns/suburbs, rural areas).
- **Inequality of income:** income inequalities can affect access to forest recreational services since individuals with higher incomes may have greater resources to invest in outdoor recreational equipment, transportation to forested areas, and participation in fee-based recreational activities such as guided tours or adventure sports. The indicator refers to the ratio of total income received by the 20% of the country population with the highest income (top quintile) to that received by the 20% of the population with the lowest income (lowest quintile).

[iv] International Standard Classification of Education

3.4. Governance and institutional arrangements

Governance and institutional arrangements are essential dimensions when designing effective forest management strategies and promoting sustainable use of forest ecosystem services. They can have important implications in enhancing the resilience and adaptive capacity of forest ecosystems to environmental change and human pressures.

Forest ownership can be considered an indicator influencing the management decisions and therefore the ecosystem services being provided, as well as the management interventions characteristics. State forest owners generally actively manage their forests according to political, societal and business objectives, paying due attention to regulation and cultural services. However, there is a wide variation in private forests, especially in small-scale forest ownership (Weiss et al. 2023). The percentage of private/public forest shares is available in a database at the NUTS2 spatial resolution (EFI, 2013).

Law enforcement and institutional arrangement, level of country corruption: Effective governance mechanisms ensure the enforcement of forest-related laws, regulations, and policies to combat illegal activities and protect biodiversity. Trust in institutions facilitates compliance with laws, social order, active citizens participation and ease of social interactions. Higher trust links to a more likely probability of citizens' respecting authority. EUROSTAT, in the "Statistics Explained — Quality of life" indicators, offers country level data on trust in political and legal systems as well as on active citizens participation and satisfaction with social interactions.

The trust for public institutions also depends on transparency in the use of public revenues, fight and control of crimes, and the perceived level of corruption, etc. The latter can be used as a proxy for the capacity of a country to effectively use public money for public services according to the society needs and satisfaction. A global corruption Perception Index per country is collected and yearly updated by Transparency International.

Government priorities and commitment to the forest sector: resource allocation (financial, human, and technical resources) to support forest management (cultural heritage and environment) conservation, and sustainable development initiatives can also influence the value of ecosystem services. Indicators proxying government commitments can be the government investment for specific functions. A collection of government spending by function, with specific categories for environmental protection, recreation, social protection, education, amenities that can be retried from EUROSTAT.

3.5. Forest accessibility, infrastructures, and accommodation facilities

The existence, quality and accessibility of transportation and communication infrastructure, such as roads, ports, airports, telecommunications networks, and internet connectivity, facilitate the movement of goods, services, and information within the sector and across markets.

The time to travel to forests from large cities can be employed as an indicator of remoteness of a forest area and can be used for different purposes when modelling both profitability of wood provisioning from forest land (modelling cost of transporting forest products to the closest

market), similarly the indicator can be considered relevant for evaluating cultural and recreational ecosystem services monetary values.

In the spatialization of values for forest cultural and recreation services there has been traditionally an evaluation including the travel time/cost for reaching a forest area (Quintano & Barredo 2015; Elasser et al. 2021, Tenerelli et al. 2016). Accordingly, an indication regarding the closeness to cities of forest areas can be relevant for spatializing recreation values (La Notte et al. 2021).

Travelling times are also needed for designing logistic systems for wood supply and computation of transportation costs for forest products to markets, since these have a strong impact on the profitability of forest management. Accordingly, in Hengeveld et al. (2012), when modelling forest management objectives across the whole EU region, closeness to cities can be considered a criterion influencing both the nature recreation value as well as the suitability of forests for wood production.

Global **travel time to cities** can be retrieved from Weiss et al. (2018), as an accessibility map of each point on a global land grid to the closest city, considering at the same time infrastructures and topography (land cover, slope, altitude). The global accessibility map enumerates land-based travel time to the nearest densely populated areas for 2015. Densely populated areas are defined as contiguous areas with 1,500 or more inhabitants per square kilometer or most of built-up land cover types coincident with a population center of at least 50,000 inhabitants.

A more detailed accessibility indicator can be calculated according to a GIS road network analysis, where a road network is overlayed with a map of cities and a forest cover map. This approach results in "**closest distance to cities",** where the shortest distance for moving from each point in a forest to a city over certain population threshold can be obtained. Results for this approach were presented in Di Fulvio et al. (2016) for the EU, when selecting cities with population thresholds according to density of forest industries in each EU country.

Road densities can be a more detailed indicator on accessibility of a forest area. In particular, the network of "local roads" could inform on areas where the density of "local roads" is under a certain threshold, that are areas where wood procurement costs are expected to increase due to the longer distance from forest stand to the roadside (Simoes et al. 2022). The GRIP database (Meijer at al. 2018) provides a global map of roads densities according to different road categories including: highways, primary roads, secondary roads, tertiary roads, local roads. The tertiary and local roads can be particularly suitable for computing mean extraction distances from forest areas, by overlay of forest cover with the road density attribute.

Tourist accommodation in a region can provide useful information regarding the potential infrastructure for hosting touristic activities. The presence of touristic infrastructure translates into greater accessibility, also favoring cultural and recreational activities, not only in forest-related areas, though. Indeed, it is worth mentioning that delegated act for EU taxonomy on sustainable finance[v] define technical screening criteria for economic activity contributing substantially to the protection and restoration of biodiversity and ecosystems also for accommodations, being within or in proximity of "areas with high nature conservation value covered by a management plan or an equivalent instrument such as a restoration plan". EUROSTAT reports the "Establishments,

[v] Commission Delegated Regulation EU 2023/2486 of 27 June 2023, Annex D (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302486)

bedrooms and bed-places in tourist accommodation" according to NUTS 2 regions. The database mentioned distinguishes amongst specific categories like "Holiday and other short-stay accommodation" and "Camping grounds, recreational vehicle parks and trailer parks" that are particularly relevant for nature recreational activities.

A complementary indicator of a region's suitability for recreational activities is provided by the **number of trips according to purpose** provided by EUROSTAT at country level. In particular, the database distinguishes from other categories a specific one named "Holidays, leisure and recreation".

4. Next steps

The list of indicators presented in this deliverable is preliminary and not yet exhaustive of all modelling needs under T4.3 and T4.4. Further refinements will be obtained when the indicators are tested in the modelling framework and when the results of the subsequent spatial extrapolation will be validated with supplementary datasets.

Pre-processing

Most of the socioeconomic indicators available are presented at either the NUTS2 or country level. Next steps will entail adapting these indicators to match the spatial scale needed for the respective models. This adaptation may require data aggregation. An adjustment of monetary currencies for some of the indicators collected in local currency units (e.g. earnings), will be obtained by applying exchange rates. For some of the indicators presenting a strong temporal fluctuation (e.g. fuel prices), we will also use averages over time periods (i.e., considering an entire year or multiple years), to reduce the effect of market volatility. Gap filling methods will be also applied for regions missing information for specific indicators. To this scope, we will cluster spatial regions having homogenous socioeconomic and forest conditions.

Selection

Some of the listed indicators are correlated to each other. An example is the obvious correlation among the macroeconomic ones (e.g. GDP and PLR). The list of substitute indicators or correlated ones is intended to address their use for various purposes in the modelling framework. Multiple similar indicators, also ensure robustness when reliance on a single indicator is insufficient for capturing the existing variability. A final selection will be performed for overlapping indicators used for the same modelling purpose. This selection process will also consider the timeframe of each indicator in relation to its intended use. This is important because certain indicators may be outdated and not suitable for representing current conditions, yet they may still be relevant for other applications.

Complementary indicators

This report focuses on socioeconomic indicators. However, in the modelling framework, there is need of combining socioeconomic and biophysical/ecological indicators, as an example to derive the "Forest area per capita" from the "Population" and "forest area". Therefore, the presented socioeconomic indicators will be complemented with biophysical indicators including forests cover, structure and biodiversity state and projections (*Table 1*). These variables will be sourced

from other tasks within ForestNavigator, where spatial analyses are being conducted (WP2, Forest4Model Datacube) or modelling is applied (WP3, G4M-X, iBIS models), as well as other data sources (e.g., protection areas databases).

Table 1: List of complementary biophysical/ecological indicators by data source

Indicator	Source
Forest area cover (status)	Forest4model Datacube (WP2)
Protected forest area (status)	WPDA 2020, protected area database Natura 2000, database
Forest structure (status and projections)	G4M-X model (T3.2)
Deadwood (status and projections)	Augustynczik et al. (2024) G4M-X model (T3.2)
Biodiversity and habitat indicators (status and projections)	iBIS model (T4.1)

Validation datasets

Other sources of socioeconomic data will be included for the validation of spatial modelling results. This will allow us to compare our results with other sources and complement them where needed. These are data available from multiple national or local sources. Amongst the available dataset that can be tested in the validation process, examples are:

- Assessments of ecosystem services values monetary values (T4.4): global datasets such as Brander et al. 2024, EU scale datasets such as Vysna et al (2021), Vallecillo et al (2018), Valecillo et al. (2019).
- National/regional collections of prices for wood products (T4.3): collections of wood prices are available from specific countries including Sweden (Skogsstyrelsen), Finland (Luke), Czechia (National Statistical Office), Poland (Drewno), France (Observatoire Economique France Bois Foret), Italy (Legno Trentino), Spain (PFCYL), Portugal (IFCN).
- Forest management cost structures observed in single countries/regions (T4.3): Slovakia (Forest Portal), Sweden (Skogsstyrelsen), Finland (Luke).

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6. Annex I

Table 2: Indicators listed by category, temporal and spatial resolution, data sources and targeted task

Category	Indicator	Temporal resolution	Spatial resolution	Data source	Targeted task
Macroeconomy	GDP per capita (PPS/inhabitant)	Yearly (2010 - 2022)	NUTS2	EUROSTAT (Table "tgs00005")	T4.4
	Purchase Level Ratio	Yearly (1990 - 2022)	Country	The World Bank (Price level ratio of PPP conversion factor (GDP) to market exchange rate)	T4.3 & T4.4
	Financial Interest rate (%)	Yearly (1991 - 2023)	Country	International Monetary Fund (Interest Rates selected indicators)	T4.3
	Consumer Price Index (Annual rate of change)	Monthly (1997-2023)	Country	EUROSTAT (Table "prc_hicp_manr")	T4.3 & T4.4
	Exchange rate (LCU/EUR)	Yearly (2012-2023)	Country	EUROSTAT/EU CENTRAL BANK (Table "tec00033")	T4.3 & T4.4
	Wood prices (LCU/m3)	2000-2019 (Monthy/ Quarterly/ Yearly)	Country	UNECE Current prices	T4.3 & T4.4
	Fuel prices excluding/including taxation (EUR/Liter)	Monthly (1997-2023)	Country	EC Energy Policy Weekly Oil Bulletin All Weekly Oil Bulletins since January 2009 Duties and Taxes	T4.3

Category	Indicator	Temporal resolution	Spatial resolution	Data source	Targeted task
Labor market, attitudes, leisure time balance and attitudes	Employment (all sectors) (1000 employee/year)	Yearly (1999-2022)	NUTS2	EUROSTAT (Table "lfst_r_lfe2emp")	T4.3 & T4.4
	Unemployment rate (%)	Yearly (2011-2022)	NUTS2	EUROSTAT (Table "tgs00010")	T4.3 & T4.4
	Employment in forestry and wood industries (thousand employee/year)	Yearly (1993-2022)	Country	EUROSTAT (Table „lfsa_egan22d" ILOSTAT Labour Force Survey	T4.3 & T4.4
	Working time (hours/year)	Every 4 years (2008-2012-2016-2020)	Country	EUROSTAT (Table "lc_nnum2_r2")	T4.3 & T4.4
	Monthly earnings per employee (agriculture, forestry, fishery) (LCU/month)	Yearly (2000-2022)	Country	ILOSTAT HIES - EU Statistics on Income and Living Conditions	T4.3
	Total tax and contribution rate on labor (% of profit)	2018	Country	The World Bank "Doing Business" (Country snapshots)	T4.3
	Leisure time balance	2018	Country	EUROSTAT, OECD, Our World in Data: https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=529719 https://www.oecd.org/gender/data/balancingpaidworkunpaidworkandleisure.htm https://ourworldindata.org/time-use	T4.4
	Attitude of people towards conserving the integrity of natural ecosystems	2007, 2010, 2013, 2015, 2018	Country	The Eurobarometer survey "attitudes of Europeans towards biodiversity" https://europa.eu/eurobarometer/surveys/detail/2194	T4.4

Category	Indicator	Temporal resolution	Spatial resolution	Data source	Targeted task
Population and social composition	Population (N persons)	Yearly (2012-2023)	NUTS2	EUROSTAT (Table "tgs00096")	T4.4
	Population density (N Persons/Km^2)	Yearly (1990-2022)	NUTS2/3	EUROSTAT (Table "demo_r_d3dens")	T4.4
	Population by sex and age (N Persons)	Yearly (1999-2023)	NUTS2	EUROSTAT (Table "demo_r_d2jan")	T4.4
	Population by level of education (N persons)	Yearly (2022-2023)	Country	EUROSTAT (Table "demo_pjanedu")	T4.4
	Distribution of population by degree of urbanization (share of total population)	Yearly (2014-2022)	Country	EUROSTAT (Table "urb_lpop1")	T4.4
	Inequality of income distribution (ratio)	Yearly (2012-2022)	Country	EUROSTAT (Table "tespm151")	T4.4

Category	Indicator	Temporal resolution	Spatial resolution	Data source	Targeted task
Governance and institutional arrangements	Percentage of private/public forest property (%)	2013	NUTS2	EFI Mapping the distribution of forest ownership in Europe Report N. 88, 2013.	T4.3 & T4.4
	Corruption Perception Index	Yearly (1995-2023)	Country	Transparency International Corruption Perception Index	T4.4
	Government Priorities: Government spending by function	2021	Country	EUROSTAT (Table "gov_10a_exp")	T4.4
	Trust in the political and legal system, by income situation	Trust 2013	Country	EUROSTAT Statistics Explained — Quality of life indicators, Category: Governance and basic rights: Trust in the political and legal system, by income situation: Figures4	T4.4
	Active citizenship by sex, age, income (16 years or over)	Active citizenship 2015	Country	Active citizenship: Table "ilc_scp19" & Figures 1, 2, 3	T4.4
	Social interactions: satisfaction with personal relationships, by age, sex, income, and degree of urbanization, for each EU country.	2018	Country	EUROSTAT, Statistics Explained — Quality of life indicators, Category: Social interactions: Figures 6, 7, 8, 9, 10	T4.4

Category	Indicator	Temporal resolution	Spatial resolution	Data source	Targeted task
Forest accessibility, infrastructures and accommodation facilities	Travel time to cities (≥ 50k inhabitants) (Minutes)	2015	30 arc-sec (≈1x1 km)	Weiss et al. 2018 A global map of travel time to cities	T4.3 & T4.4
	Average distance from cities to the closest forest (km)	2023	5 arcmin	NASA SEDAC World Cities Database Open Street Map (OSM) Road database	T4.3 & T4.4
	Road density (m/km^2)	2024	5 arcmin (≈10x10 km)	Meijer et al. 2018 GRIP database	T4.3 & T4.4
	Tourist capacity (number establishments)	Yearly (2000-2022)	NUTS2	EUROSTAT (Table "tour_cap_nuts2")	T4.4
	Trips by purpose (number of trips)	Yearly (2012-2022)	Country	EUROSTAT (Table "tour_dem_ttpur")	T4.4