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Resilient Forests for Society

Deliverable 1.3

Trade-offs assessment

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Table of Contents

Executive Summary 3
Keywords 3
Abbreviations 4
1. Introduction 5
2. The origin of trade-offs 6
2.1 Approach to uncover trade-offs of forest ecosystem services and value chains 7
2.1.1 Forest ecosystem services and value chains 7
2.1.2 Understanding resilience and related challenges 9
2.2 Identification of resilience-related trade-offs 10
2.3 Procedure for the selection and building of specific key indicators and predictors 14
3. Assessment: Attribution of system variables to the selected key trade-offs and availability of data 16
3.1 Trade-offs and evidence-bases for selected countries 16
3.1.1 Trade off: Carbon sequestration (in forests) and carbon storage in Harvested Wood Products/ Carbon sequestration (in forests) and wood use 28
3.1.2 Trade-off: Biodiversity and bioeconomy 28
3.1.3 Excursus: Imports and consumption 28
4. Conclusions: Synergies and Balances of Trade-offs 28
5. References 29

Executive Summary

This deliverable (D 1.3) is a report on trade-offs and synergies between resilience indicators in the context of ecosystem services and forest-based value chains. It includes the description of a procedure for the selection of specific key system characteristics for resilience effects (Del. 1.1, Hurtado et al. 2022) based on multiple variables. It benefits from the assessment of functional properties of the social-ecological system and related co-drivers developed in Task 1.2. For this, it uses the international classification of ecosystem services (CICES) and collects the available data for the whole forest-based value chain (Wolfslehner et al. 2016). The framework on trade-offs developed here will be used for the forthcoming integrated ecosystem and value-chain resilience assessment in Task 5.2. It will also feed into the policy recommendations developed in Task 5.4.

For these purposes, this report outlines the origin of trade-offs (section 2) and links them with the forest-based sector value chains (section 2.1). The results identify key trade-offs from the literature (section 2.2) and relate these trade-offs to their respective balancing synergies, provided in a table (Table 1). For the subsequent trade-offs assessment (3) available national data is searched and applied along the CICES classification. The assessment is predicting the respective resilience effects (predictors), provided as tables (Tables 2-4). It finally discusses synergies as positive sides for increasing the resilience of ecosystems and value chains under the paradigm of multipurpose forestry (section 4).

Keywords

Eco-system services, trade-off identification, resilience management, forest value chain, multicriteria assessment, resilience increase assessment

Abbreviations

C&I – Criteria and indicators
CBD – Convention on Biological Diversity
CEC – Cation exchange capacity
CFRQ – Collaborative Forest Resources Questionnaire
CICES – Common International Classification of Ecosystem-Services
CIFOR – Center for International Forestry Research
CMEF – EC Common Monitoring and Evaluation Framework for Rural Development Indicators
EC – European Commission
Eurostat – European Statistics (The statistical office of the EU)
EU – European Union
EEA – European Environment Agency
FAO – Food and Agriculture Organization of the United Nations
FMU – Forest management unit
FRA – FAO Forest Resource Assessment
FSC – Forest Stewardship Council
GDP – Gross Domestic Product
GVA – Gross Value Added (=GVA provides a Euro value for the amount of goods and services that have been produced in a country, minus the cost of all inputs and raw materials that are directly attributable to that production. GVA thus adjusts gross domestic product (GDP) by the impact of subsidies and taxes (tariffs) on products)
IAEG – UN Inter-Agency Expert Group on SDG indicators
IAF – International Arrangement on Forests
ILO – International Labour Organization
IPCC – Intergovernmental Panel on Climate Change
ITTO – International Tropical Timber Organization
IUCN – International Union for Conservation of Nature and Natural Resources
JFSQ – Joint Forest Sector Questionnaire
JQ – Joint questionnaire
JWEE – Joint Wood Energy Enquiry of the UNECE/FAO Forestry and Timber Section
LFCC – Low Forest Cover Countries
LULUCF – Land use, land-use change and forestry
MCPFE – Ministerial Conference on the Protection of Forests in Europe (Forest Europe)
MEA – Millenium Ecosystem Assessment
n.a. – not applicable
NAI – Net annual increment
NFI – National forest inventory
OECD – Organization for Economic Co-operation and Development
PEFC – Programme for the Endorsement of Forest Certification Schemes
PFE – Permanent forest estate
R&D – Research & Development
SDG – UN Sustainable Development Goal
SFM – Sustainable forest management
UNCCD – United Nations Convention to Combat Desertification
UNDA – United Nations Development Account
UNECE – United Nations Economic Commission for Europe
UNFCCC – United Nations Framework Convention on Climate Change
UNFF – United Nations Forum on Forests
WS – Workshop
yr – year

1. Introduction

This deliverable (D 1.3) is a report on trade-offs and synergies between resilience indicators in the context of ecosystem services and forest-based value chains. It includes the description of a procedure for the selection of specific system variables or resilience predictors based on multi- criteria tools. Our definition of "indicators"[1] leans on the commonly used FAO definition on Criteria and Indicators for Sustainable Forest Management (2022), stating that:

> *"Indicators are parameters which can be measured and correspond to a particular criterion. They measure and help monitor the status and changes of forests in quantitative, qualitative and descriptive terms that reflect forest values as seen by those who defined each criterion*" (FAO, 2022).

Foregoing deliverables in the RESONATE project (Del. 1.1, Hurtado et al. 2022) have developed an inventory of resilience indicators and metrics. They apply this definition of the term "indicators" by way of two different notions: (1) descriptors of the properties of the system which is experiencing resilience (e.g., the resilience of carbon storage under climate change can be estimated by the performance of the indicator "forest stand biomass"), and (2) predictors of the resilience of given properties of the system. One example is that higher "stand tree diversity" can be an indicator of higher resilience of timber production under climate change) (Hurtado et al. 2022, p. 4). What is positive and what is negative for resilience is shown using resilience predictors, referring to a specific resilience challenge (Chapter 2.1.2, Hurtado et al. 2022). The specific example for predictors is valid for the "stand" level, but not on a national level. For the trade-offs assessment (Del.1.4) the measurement of the proposed indicators was taken for national levels (not stand level) for reasons of comparability of forest-related data. Furthermore, the reported inventory (Hurtado et al. 2022) has adopted two different terms describing the abovementioned two distinct meanings of indicators: respectively, "system variables" (1) and "resilience predictors" (2). The trade-offs assessment was carried out in Task 1.4 (Balancing resilience trade-offs and synergies to support decision-making and management) and builds on the Resilience Dashboard developed in the RESONATE project (Del. 1.5).

The results will feed into the integrated forest ecosystem and value-chain resilience assessment in Task 5.2 (Integrated policy assessment). In what follows, we will outline the results from the state-of-the-art in the literature on the origin of trade-offs (section 2) and link them with the forest-based sector value chains (section 2.1). Along these lines, we identify key trade-offs from the literature (section 2.2) and relate these trade-offs and respective synergies for balancing, provided in a table (Table 1). For the subsequent trade-offs assessment (3) available national data is searched and applied along the CICES classification. The assessment is predicting the respective resilience effects (predictors), provided as tables (Tables 2-4). It further presents data gaps, the availability of data and the limits of results (section 3.1.1 – 3.1.4). The report provides indicative conclusions for balancing these trade-offs through synergies (section 4).

Finally, this report on the RESONATE trade-offs assessment provides the systematic collection, review, and use of information about the different trade-offs amongst diverse forest ecosystem services for the improvement of long-term planning, and policy decision-making. It serves as the scientific basis for the further implications for Policies and policy mapping of the relevant policy instruments in WP 5 and it feeds into Del. 5.2.

[1] The term „indicator" is used in forest research depicts the „Monitoring, assessment and reporting of indicators"(e.g. FAO 2022).

2. The origin of trade-offs

Ecosystems, such as forest ecosystems provide multiple ecosystem services at the same time. Along the forest-based value chains, the actors involved in decision taking are administrative decision-takers, producers, processors, consumers, nature protection NGOs, municipalities, forest owners and other stakeholders. Since it is not possible to manage ecosystems to maximise all ecosystem services simultaneously, trade-offs occur when the provision of one ecosystem service or product is reduced or increased at the use of another product or ecosystem service (Guntsch et al. 2018; Lafond et al. 2017; Locatelli et al. 2014; Dunbar et al. 2012; Schwaiger et al. 2019; Turner et al. 2014; Verkerk et al. 2014). The following figure (Figure 1) is illustrating this relationship.

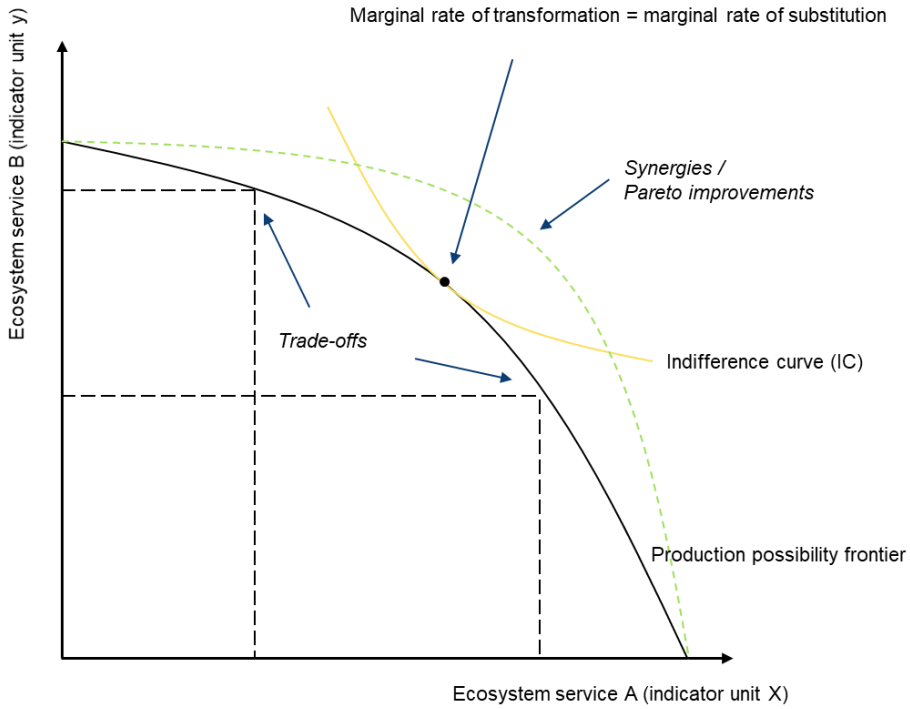

Figure 1 Ecosystem Services trade-offs and synergies

According to Figure 1, trade-offs between two ecosystem services (A & B) are shown below the production possibility frontier curve. It illustrates how a forest management decision can lead to an increase in one service and a decrease in another service. The production possibility frontier is a constraint on choices. It represents the trade-off that one must make between ecosystem services. At any point on the frontier, focusing management on one ecosystem service has an opportunity cost in terms of the other ecosystem service, corresponding to the slope of the frontier. The production possibility frontier marks a functional threshold of the current biophysical provision limit of a certain ecosystem service. It shows the “marginal rate of transformation”, i.e. the rate at which one can transform one ecosystem service into another. The “marginal rate of substitution” measures the trade-off that one is willing to make between the ecosystem services. The indifference curve joins together combinations of the ecosystem services that shows all the points of equal level of “utility”. The slope of the indifference curve highlights the trade-offs; one is willing to make between ecosystem services. If we assume that utility maximization is the goal, the optimal combination of the ecosystem services is a point on the feasible frontier where the marginal rate of transformation is equal to the marginal rate of substitution.

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In summary, the indifference curves indicate what one prefers, and their slopes shows the trade-offs that one is willing to make; the feasible frontier is the constraint on one´s choice, and its slope shows the trade-off one is constrained to make.

Synergies are described by an improvement of the pareto state, and made visible by an extension of the production possibility frontier.

For the endeavour, a trade-off as such is not the problem, the problem is located **in the effects of trade-offs**. The effects of trade-offs can further be classified along (A) spatial scale or (B) temporal scale.

a) **Location or spatial scale** refers to whether the effects of the trade-offs are noticeable locally, regionally or nationally.
b) **Time or temporal scale** refers to whether the effects are noticeable in the short, medium or long-term future.

For further decision-taking, **information and knowledge** are decisive. Information and knowledge are necessary firstly for the identification of trade-offs, and secondly, for the effects of the trade-offs. Most notably synergies may balance trade-offs between different management options. Moreover, the trade-off between forest protection and sustainable forest management can be avoided using the so-called “close-to-nature forestry” (Bieling, 2004, Larsen et al. 2022).

The following section will outline the methodological framework employed for the assessment of trade-offs. Section (1.2.) will define our operationalization of ecosystem services for the trade-offs assessment in more detail. For this purpose, we will use the Common International Classification of Ecosystem Services (CICES) (see section 1.2, below).

2.1 Approach to uncover trade-offs of forest ecosystem services and value chains

2.1.1 Forest ecosystem services and value chains

Forests provide wood for material and energy use. At the same time, forests also store carbon, preserve soils, create oxygen, regulate water regimes, are biodiversity hotspots and places for recreation. All these benefits are known as “ecosystem services”.

As UNECE/FAO (2020) put it: “… there are increasing demands on forests, for carbon sequestration, for renewable bio-based materials and products which can substitute non-renewable ones, for rural livelihoods, and for recreation, all in the context of a rapidly changing climate. There are calls for modified silviculture to meet the new demands and to adapt to changing climate conditions. There are, undoubtedly, **limits to the forests’ capacity to respond to these demands, which necessitate trade-offs between** them”.

Only some of the ecosystem services are part of the wood-based value chain, although the provision of wood is the most regularly marketed forest ecosystem service. We acknowledge, that there are multiple value chains in a forest. Since many of the identified trade-offs in RESONATE are related to timber production (Jankovský et al. 2022),

The following figure (Figure 2) sketches the forest-based sector value chain ranging from carbon storage in forests, forest management, non-wood goods, services (such as recreation, illustrated here with mountain biking), timber, transport of logs, primary wood products,

trade/export, processing, transport of wood products, consumption, recycling and end use in thermal power plants.

Figure 2: The forest-based sector value chain, (design: Gabriela Rueda, RESONATE project)

To categorise the distinct elements of forest-based value chains for the trade-off assessment, we use the **Common International Classification of Ecosystem Services (CICES)**, in its classification version 4.3[2]. The classification scheme has the advantage that it splits the value chain into several sections and further divides them into divisions and class types, allowing for a detailed analysis.

For what are regarded as potential or putative "final ecosystem services", CICES describes them using a **five-level hierarchical structure**. Each level is progressively more detailed and specific. The way the system works can be illustrated for the contributions that ecosystems make to a cultivated crop:

- **Section** (Provisioning)
- **Division** (Biomass)
- **Group** (Cultivated terrestrial plants for nutrition, materials or energy)
- **Class** (Cultivated terrestrial plants [including fungi, algae] grown for materials)
- **Class type** ("Roundwood". The ecological contribution to the growth of cultivated, land-based crops that can be harvested and used as raw material for the production of products)

[2] https://biodiversity.europa.eu/ecosystems/mapping-and-assessment-of-ecosystems-and-their-services-maes-1/common-international-classification-of-ecosystem-services-cices, last access 2022-06-13

For example, the **main categories of ecosystem services** are divided as follows into the above-mentioned sections: **Provisioning** [Nutrition, Materials, Energy]: **Regulation & Maintenance** [Mediation of waste, toxics, and other nuisances; Mediation of flows, Maintenance of physical, chemical, biological conditions]; and **Cultural Products and Services** [Physical and intellectual interactions with biota, ecosystems, and land- /seascapes (environmental settings); Spiritual, symbolic and other interactions with biota, ecosystems, and land- /seascapes (environmental settings)].
For the trade-offs assessment, we have used CICES to attribute ecosystem services and related trade-offs to specific sections of CICES and filled them with the data that were available[3] from the following three Databases: INForest https://forest-data.unece.org/Indicators; Forest Europe https://forest.eea.europa.eu; FRA https://fra-data.fao.org; Eurostat: https://ec.europa.eu/eurostat/databrowser/view/.

Regarding observations related to trade-offs along of wood-based value chain, we applied value chain divisions and identified the available data as measurable information (= as parameters that are measurable and correspond to a particular criterion, FAO 2015a), along the following **categories:**

- Forest management;
- Transport;
- Production of primary wood products (including Carbon storage);
- Trade;
- Maintenance of secondary wood products;
- Thermal end-use

For non-wood forest products like berries, nuts, honey or resin, no value chain categories could be built, since available data on NWFPs are mostly incomplete and difficult to compare. For instance, the data available on non-wood goods were extracted from the Forest Europe database (https://forest.eea.europa.eu, 3.3.). Nevertheless, the total value for marketed NWFP is most likely underestimated as the marketed NWFP represent only a small share of all consumed goods (Lovric et al. 2021)

Similarly, other ecosystem services, like air production, biodiversity are “public goods”, which are traditionally not marketed and thus difficult to quantitatively value. Thus far, these services could only be considered qualitatively and have been discussed in two focus group discussions in a stakeholder workshop in Vienna on September 29th 2022. It is worth to mention that the identified trade-offs for this deliverable are related to the wood-based value chain. Nevertheless, if quantitative data allows to analyse other ecosystem services, this is possible in the same way as the trade-offs presented in chapter 2, by using the Resilience Dashboard (D1.5) , currently developed in the RESONATE project.

The subsequent sections are outlining the methodological approaches for our identification of key trade-offs and how we link them with resilience.

2.1.2 Understanding resilience and related challenges

The four major resilience challenges defined in the RESONATE project are:

1. Adapting to changing tree species suitability;

[3] In the case of data gaps, these were left blank (n.a. for not applicable). For better explanatory power only the data from 2010 to 2020 (reporting in 3 periods: 2010, 2015, 2020) was used. The reporting periods from **before 2010 were not** included, because the reporting method had changed significantly in 2010.

2. Coping with large stand-replacing disturbances;
3. Addressing changes in societal demand; and
4. Tackling biodiversity decline

"Resilience", originally stemming from the Latin *"resiliere"* (jumping back), denotes the ability to recover from a stressful event (a "stressor", Hurtado et al. 2022). We are further leaning on Annarelli et al. (2020), where resilience is understood as "Preparedness" for unforeseen events and the (estimated) best preventive measures to minimize (unforeseen) threats and crisis. Nikinmaa et al. (2020) identify three concepts of resilience in their extensive review of the current scholarly literature:

- **Engineering resilience** as the quantification of resilience via the recovery time needed after disturbance[4]. According to the studies covered in review of Nikinmaa et al. (2020), the two most often used indicators for engineering resilience in forestry are basal area increment and vegetation cover.

- **Ecological resilience,** as defined by Holling (1973), is "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." This concept is not focusing on the recovery time (to a predetermined state) but on the robustness and resistance of an ecological system.

The third, much less used but holistic concept of resilience, that we use in our assessment is:

- **Social-ecological resilience,** which has by far the most holistic perception of resilience but is least appearing and applied in scholarly research today (Nikinmaa et al. 2020). One reason is probably the methodological difficulties for the measurement of the societal aspects involved here. Social-ecological resilience considers natural and social systems to be intertwined and the ultimate focus would be the strengthening of the adaptive capacity of a human-natural system, imagined as coupled (Quinlan et al. 2016). All variants of this resilience concept part on such an adaptive capacity for the whole social-ecological system (Folke 2016). Some system variables used in this literature for such "adaptive capacity" are socioeconomic diversity and stock of natural resources. Nikinmaa et al. (2020) expected an increase in studies adopting the more holistic social-ecological resilience concept, but this was not the observed trend.

Thus far, one main reason for the exceptionality of empirical applications of social-ecological resilience in scholarly research is probably rooted in the "holistic" view and the subsequent difficulties in the identification of system boundaries. Most notably, some aspects of resilience of social-ecological systems cannot easily be quantified.

To link the concept of resilience to trade-offs (cf. Nikinmaa et al. 2023), we conducted a literature review to identify specific key trade-offs and synergies between system variables in the context of ecosystem services and forest-based value chains.

2.2 Identification of resilience-related trade-offs

Along the lines of the respective literature, we have identified the principal trade-offs mentioned in the literature and the challenges that these pose for resilience. For better structuration we

[4] It has to be noted here that, according to Hurtado et al. (2022) engineering resilience is often measured comparing systems after the disturbance to undisturbed or pre-disturbance states, given that full recovery is not always attained or continued records to precisely obtain a full recovery time are not available.

linked the key trade-offs with the international ecosystem services classification (CICES, as outlined above). The trade-offs are supported by specific perspectives on the problem at hand. For some trade-offs, there are **long-term debates** behind (for instance the debate about the interpretation and policy implications derived carbon storage in forests and the delay in the climate benefit of wood use). Others are backed-up by **principal policy strategies** (for instance the strive for enhancement of bioeconomy for replacement of fossil fuels and the strive for strict protection of forests for biodiversity enhancement). Different time and impact horizons, system boundaries and indicators can lead to difficulties for univocal interpretations of trade-offs. Furthermore, we found in our stakeholder discussions, that the perception of trade-offs varies between stakeholders, depending on their perceptions and preferences.

Trade-offs linked to the question of management and timber extraction, or the strive for un-managed forest and protection of forests can be reduced or avoided through alternative management options. Possible synergies can be achieved with “multi-purpose forestry”, and have more recently gained prominence as so called “close-to-nature” forestry (Larssen et al. 2022, Bieling 2004). Hitting into a similar vein, the notion “Climate Smart Forestry” aims at reconciling this trade off by creating resilient forests and maximising climate benefit of wood use, while considering biodiversity (Bowditch et al. 2020; Nabuurs et al. 2018; Verkerk et al. 2020).

We identified possible synergies that may partially balance all the identified main trade-offs. The following table (1) presents the results of our literature analysis on forest-related trade-offs, the differing perspectives behind and the possible synergies. It outlines the respective literature and connects the trade-offs with the ecosystem service classification (CICES) section for our further assessment. Furthermore, we have included the related literature references with the identified trade-offs. All results are presented in table 1, hereafter.

Table 1: Key trade-offs identified from literature, resilience challenges (according to RESONATE Definition), differing perspectives and possible synergies

CICES Section[5]	Main Resilience challenges (RESONATE Definition)	Potential Trade off	Differing perspectives	Possible synergy measures / Synergetic actions to minimize trade-offs	Main References
Regulation & maintenance	Addressing changes in societal demand	a) carbon storage (in forests) and b) carbon storage in Harvested Wood Products/wood use	Scientific debate behind: a) Is it better to store CO_2 in the forest (living biomass, forest soils) or b) the main forest management objective to be maximum of sustainable fellings for carbon stored in HWP? The considered period of time is decisive for both questions: Do we get more climate benefits by a) leaving biomass in the forests or b) using it in products and for energy generation?	Enhancement or maintenance of carbon stock and sinks in active forest management (closer-to nature forestry/ Climate-smart forestry)	*EC, 2021 (New EU Forest Strategy 2030)* *Larsson, B. et al. 2022* *Seidl et al., 2007, doi: 10.1016/j.foreco.2007.02.035* *Richards and Stokes, 2004, doi: 10.1023/B:CLIM.0000018503.10080.89* *Chen et al. 2016* *Carpentier et al. 2017*
Regulation & maintenance AND Provisioning	Tackling biodiversity decline and Addressing changes in societal demand	c) biodiversity (Nature Protection) and d) bioeconomy (Forest Management)	a) logging leads to negative impacts for biodiversity versus b) logging and the sustainable use of natural resources are needed for the circular bioeconomy.	Introduction of closer-to-nature forestry with e.g. mixed stands and continuous cover forestry and applying innovations in wood utilization methods or increase the rate of reuse and recycling to alleviate the pressure on virgin resources (i.e. cascading uses of wood). Another possible measure: Segregation: Forest areas for timber production and forest areas for nature protection	*EC, 2021 (New EU Forest Strategy 2030)* *Larsson, B. et al. 2022 (Closer-to-nature forestry)* *Bastos Lima, et al. 2022* *Ludvig et al., 2019, doi : 10.3390/f10100878* *Ledermann et al. 2021*
Regulation & maintenance AND Provisioning	Addressing changes in societal demand	a) Increasing protection and b) increasing wood use (consumption)	The Green Deal requests a) 10- to 30% of the forest area under protection, at the same time	Imports only from countries where it is guaranteed that the timber resources are from sustainably managed forests (EU-TR)	*The Green Deal (EC, 2019),* *Sinabell and Streicher 2021,* *Rüter et al. 2016*

[5] CICES (*common classification of ecosystem services)* https://cices.eu/cices-structure/

CICES Section[5]	Main Resilience challenges (RESONATE Definition)	Potential Trade off	Differing perspectives	Possible synergy measures / Synergetic actions to minimize trade-offs	Main References
			b) requests to increase the utilization of renewable resources, i.e. timber. Thus, to increase consumption of wood products an increased import from wood resources from outside the EU countries would be necessary. Threat of Carbon leakage.		
Provisioning	Addressing changes in societal demand	a) Timber provision and b) demand for recreational activities	a) The main economic benefit of a forest is timber production from perspective of many forest owners versus b) (societal) demand for recreational benefits (such as hiking, leisure and sports activities, e.g. mountain biking)	Diversification of forest management goals and introduction of recreational zones.	*Wilkes-Allemann et al., 2022, doi: 10.1016/j.forpol.2021.102683* *Harshaw and Sheppard. 2003: Assessing timber harvesting impacts to recreation in areas adjacent to parks and protected areas.https://www.researchgate.net/publication/266331669_ASSESSING_TIMBER_*
Provisioning	Addressing changes in societal demand	a) Nature Protection and b) recreational activities	a) Forest protection (e.g. in nature protection areas) is in opposition to (cannot be hampered by) b) recreational activities (such as hiking, leisure and sports activities, e.g mountain biking)	Agreement on recreational zones minimizes potential trade-offs.	*Vejre et. al. 2010* *Wilkes-Allemann et al., 2022, doi: 10.1016/j.forpol.2021.102683*

Source: Own elaborations by authors.

For the intended trade-off assessment, we will continue along the lines of the necessity of building indicators and predictors on the basis of available data and information (subsequent section 2.3). These indicators and predictors allow to quantitatively link trade-off elements and highlight their trend and severity, based on the available data. Hence, the following subsection is outlining out procedures for selection and building of suitable indicators and predictors.

2.3 Procedure for the selection and building of specific key indicators and predictors

After key trade-offs have been identified, we aim to connect these with associated indicators and predictors to assess whether trade-offs (i.e. goals which are not attainable at the same time or go to the costs of other goals) or synergies become apparent, and whether data confirms the identified trade-offs.

For this report, criteria and indicators (C&I) are tools used to define, guide, monitor and assess progress/trade-offs and synergies to tackle resilience challenges (section 2.1.2) in a given context (Linser, 2021). Indicators are used in **monitoring, evaluating and communicating progress towards more general targets** formulated in the respective criteria (maintain, enhance, provide, and secure certain aspects covered in indicators) or towards specific targets (quantitative or qualitative), set for each indicator. The comprehensive information provided by criteria and indicators should help understanding and inform the discussion about strengthening resilience. An exhaustive list of identified indicators can be found in Annex 1.

For the monitoring, assessment and reporting on sustainable forest management (SFM) C&I for sustainable forest management (SFM) have been developed during the last 30 years (Linser et al, 2018 a and b). They operate at the global, regional, international, national, subnational, and also at forest management unit levels. For the topic of resilience trade-offs we have developed a process in order to tailor C&I not only for SFM but also in consideration of the bio-economy, SDGs and biodiversity requirements.

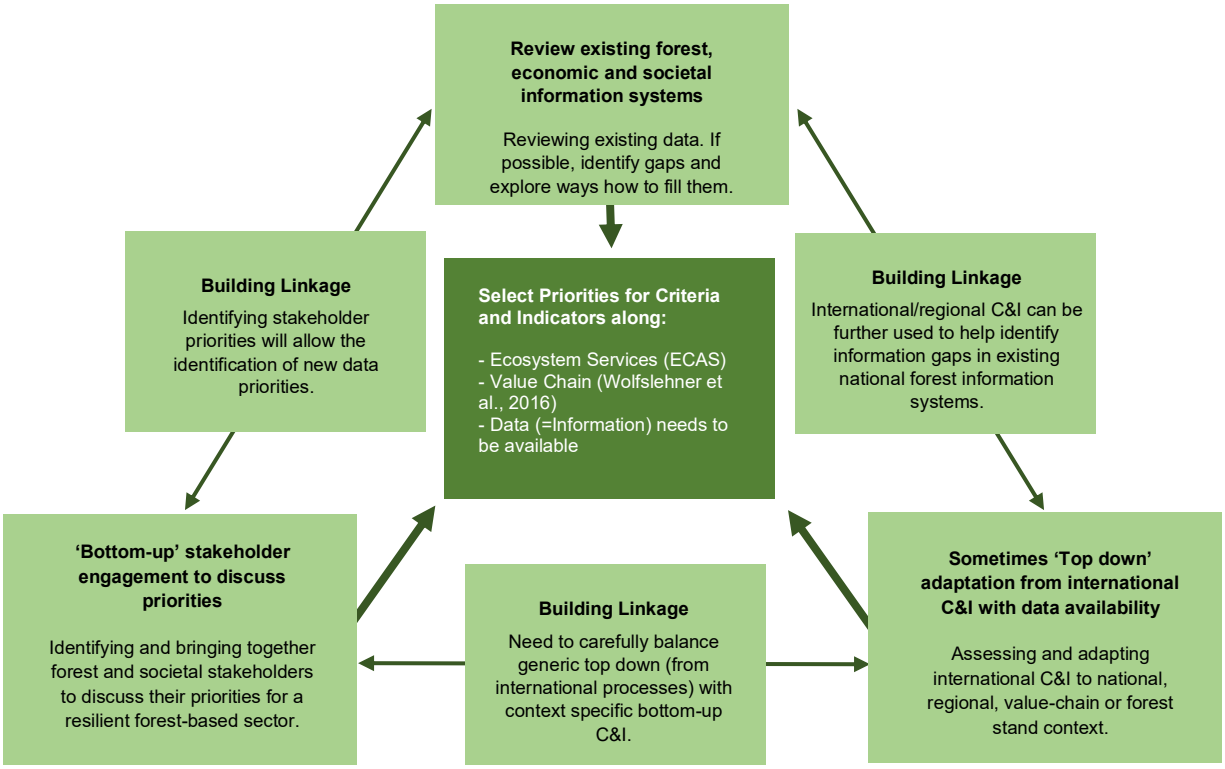

Figure 3: procedure for selection and building of specific key indicators
Source: Adapted by authors from Linser and O`Hara, 2019 (Figure 8, p.24)

The principal selection criteria (Figure 3) are priorities for the RESONATE project along the forest-based value chains and the services produced and provided there, under consideration of the data available for the assessment of trade-offs. For this, in the first step, existing information systems were screened (data bases INForest https://forest-data.unece.org/Indicators; Forest Europe https://forest.eea.europa.eu; FRA https://fra-data.fao.org; Eurostat: https://ec.europa.eu/eurostat/databrowser/view/.) along the value chain (Wolfslehner et al. 2016) and by using the classification of CICES for covering the ecosystem services involved.

As mentioned above, we will lean on the FAO-definition of indicators, according to which *"Indicators are parameters which can be measured and correspond to a particular criterion. They measure and help monitor the status and changes of forests in quantitative, qualitative and descriptive terms that reflect forest values as seen by those who defined each criterion"* (FAO, 2015a). But what is the difference between an indicator and other data? Indicators reduce large quantities of data to a simpler form, retaining essential meaning for the questions that are being asked of the data or to be representative of the criteria they are aligned to (Linser et al. 2018 a, Ott, 1978).

It is important to note, that **indicators are always one- or two dimensional figures**, like "forest area" or "forest area per capita" being two often applied indicators. Indicators shall not be confounded with "indexes"; which are weighted, multidimensional aggregated data without single units (Linser et al, 2018 a and b).

3. Assessment: Attribution of system variables to the selected key trade-offs and availability of data

In the next step, we have identified system variables (Hurtado et. al. 2022) **to each of these trade-offs** and searched for the data available for these system variables in the above-mentioned data bases. In order to **assess the results in terms of their resilience effects, we took the data for a time-scale from 2010 to 2020,** which is a short timeframe, but enough to showcase the approach in line with the Resilience Dashboard, that has been developed in the RESONATE project (Del 1.4), to assess trade-offs regarding their resilience impact.

For better illustration of the development of the data as predictors for resilience we have done the same for three European countries: Austria, Finland and Portugal, all have different forest conditions, different wood value chains and located in three different European regions, North, Central and Southern Europe. We used the CICES criteria for identification of the respective ecosystem services. The data sources are referenced in the tables.

The assessment aims at presenting the positive effects on resilience of various aspects of the wood-value chain. It has to be noted that the information across the three countries illustrates trends and not comparable measurements across the time span. It rather shows short-term trends for these predictors and connects to the operability of the Resilience Dashboard (forthcoming Del. 1.4).

In the following tables, system variables are describing the social-ecological system. System variables are therefore understood as quantitative expressions of systems characteristics. Resilience Indicators are parameters that inform about the resilience of system variables (Hurtado et al. 2022), in our case what we interpreted to be beneficial for resilience (positive effect for resilience prediction).

3.1 Trade-offs and evidence-bases for selected countries

To showcase exemplarily trends and severity of identified trade-offs (Table 1), we use key indicators and predictors, pertaining to the respective trade-off. These indicators have been identified according to our approach in section 2.1.

It is important to highlight that the results have several constraints. Firstly, due to different natural and legal framework conditions a comparison between countries is not possible without further investigation of the national or regional context to ensure comparability. For example, Camia et al. 2018 state that lacking comparability of national forest-related statistics is still an issue today and in the following they estimate that high uncertainties are associated to reported wood removals, which are most likely to be underestimated. Secondly, the results presented below in tables 2-4 should showcase examples in terms of information from the Resilience Dashboard (Demonstrator, D. 1.5).

Since data availability as inputs for the Resilience Dashboard has been limited, users of the dashboard are welcome to use more precise temporally and spatially data to improve the informative value of the results and tailor the results to their specific needs. For example, we used a quite short timeframe to showcase the results more clearly, although it is obvious that due to the typically long rotation period in European forests, trends in the trade-offs are most likely only visible in long-term observations. We used data from Forest Europe, which are published every five years. The next comprehensive data collection round will be finalised in

2025. Since market related values can change a lot from one year to another, using a 5-year monitoring interval could give a better picture of market related trends.

Overall, we found that there is still poor overall data quality and data gaps present. Finally, some of the indicators do not consider import and export of roundwood. This limits the explanatory power of the results. We advise including data on import and export of roundwood to get a clear picture of present trade-off trends.

To validate the presuppositions on trade-offs based on our literature review, we used **two focus group discussions in a stakeholder workshop in Vienna on September 29th 2022** on trade-offs and synergies for Social-Ecological Resilience. Group 1 focused on trade-offs linked to carbon sequestration in forests and carbon storage in Harvested Wood Products as well as trade-offs linked to material or energetic use of wood. Group 2 focused on trade-offs linked to nature protection, wood consumption and recreational activities. Focus group discussions revolved around the question of how the presented trade-offs are perceived, how important biodiversity and bioeconomy are perceived for resilience and whether synergies to balance the identified tradeoffs can be identified. After the discussions, participants were asked to estimate severity of identified trade-offs over different time horizons, until 2100 to get an estimate of the development of trade-offs under current policy framework. We introduced these expanded time horizons to get information beyond the available data presented in the trade-offs tables below (2010-2020).

In the following, the results of the Resilience Dashboard for the identified trade-offs are presented and complemented with evaluations from the focus groups.

The column “positive effect” in tables 2-4 serves as a reminder on what trend we will perceive as a positive effect for resilience pertaining to a specific “resilience challenge” The calculations of positive and/or negative impacts for resilience are comprehensively outlined in the RESONATE Resilience Dashboard (D. 1.5).

In line with current EU Resilience Dashboards[6] (which all use broad sets of **indicators** to the relative strengths and weaknesses of countries) we apply coloration for showing these relative strengths and weaknesses. The coloration illustrates the trends identified: **Green** coloring means an “**increase of resilience”** over the years. **Red** is pointing out a “**decrease of resilience**” over the selected years, which means a negative effect. **Yellow** indicates no change to the reference state in our data in 2010. When there is no increase/decrease, then the cell is marked in white, same goes for the years where there is no data available. If there all considered system variables are stable or increasing according to the resilience predictor at the same time there is no sign of trade-off in the data. If at least one of them decreases there is sign of trade-off.

[6] https://ec.europa.eu/info/strategy/strategic-planning/strategic-foresight/2020-strategic-foresight-report/resilience-dashboards_en

3.1.1 Trade off: Carbon sequestration (in forests) and carbon storage in Harvested Wood Products/ Carbon sequestration (in forests) and wood use

Table 2 illustrates national data of selected countries on carbon sequestration (in forests) and carbon storage in Harvested Wood Products (HWP) as well as the available data on fellings. As a system variable for carbon sequestration, the carbon stock in forest biomass has been used. Data on the carbon stock in HWP has been used as the second system variable. To ensure that harvest levels remain under sustainability threshold, the amount of fellings to net annual increment (NAI) has been listed in the table.

Climate change might affect forests, thus leading to long-term change in the growing stock available for wood supply. Furthermore, several EU policy discussions are perceived to tend towards accumulating more carbon stock in forest biomass, e.g. biodiversity strategy, LULUCF, nature restoration, which could influence the overall harvest levels. Simultaneously, EU-notions require sustainably sourced products for a bioeconomy. This raises the question of the realizable potential of woody biomass for a bioeconomy. Several studies investigate this question (Verkerk et al. 2011, Camia et al. 2018), which is inter alia dependent on the policy framework. Our focus group discussions in this context revolved primarily around the influence of increased disturbances due to climate change. Participants argued, that managing forests with the sole objective of carbon sequestration in forests puts forests in danger, due to the expected increase of disturbances due to climate change. In this context, some of the focus group participants saw resilience advantages to harvest wood and make products out of it, especially because wood is one of the few non-fossil re-growing raw materials at present in the EU.

However, the time series figures for both system variables increased or remained stable as the underlying forest area and the growing stock were increasing or remained stable (see tables below). The color scheme shows maintenance and/or slight increase in all the resilience predictors, thus no trade-off in this regard is visible. This can be explained by several factors: First, the time-frame of 10 years might be too small, to identify key trends. Second, data on the predictors are not include roundwood imports, which could offset the reality of the trade-off in a country. As Chen et al. (2016) highlight: “economic and ecological trade-offs are typically uncertain, vary at temporal and spatial scales, and are difficult to measure”. Third, current policy foci will show their effect with some time delay. Most notably, the trade-off between forest protection and wood use has been identified as the most prominent trade-off between all focus group participants.

CICES section	Resilience challenge RESONATE	System variable	Austria			Finland			Portugal			Resilience prediction (Positive Effect)	Data source
			2010	2015	2020	2010	2015	2020	2010	2015	2020		
Regulation & maintenance	Adapting to changing tree species suitability	Carbon stock in forest biomass (million metric tonnes)	385.4	393.3	401.2	780.1	863.6	863.6	84.1	85.6	n.a.	An increase is positive for the resilience of forest ecosystems to a changing climate	FRA/Forest Europe database (1.4
-	Addressing changes in societal demand	Carbon stock in harvested wood products (million metric tonnes)	62.5	64.8	n.a.	94.0	97.2	n.a.	1.0	1.2	n.a.	Increase is positive for the resilience to a changing climate via long time carbon storage	FRA/Forest Europe database (1.4
Regulation & maintenance	Addressing changes in societal demand	Fellings in forest available for wood supply (m^3/ha) (FE 3.1)	7.1	7.1	n.a.	3.3	3.9	n.a.	n.a.	n.a.	n.a.	An increase in fellings increases the resilience to changes in societal demands concerning fulfilling wood-related natural resource needs	FRA/Forest Europe database (3.1
Regulation & maintenance	Addressing changes in societal demand	Fellings as a percent of net annual increment (%) (FE 3.1)	87.1	87.1	n.a.	68.5	80.4	n.a.	n.a.	n.a.	n.a.	An increase in fellings as percent of net annual increment up to 100% increases	FRA/Forest Europe database (3.1

CICES section	Resilience challenge RESONATE	System variable	Austria			Finland			Portugal			Resilience prediction (Positive Effect)	Data source
			2010	2015	2020	2010	2015	2020	2010	2015	2020		
												the resilience to changes in societal demands concerning fulfilling wood related natural resource needs	

Table 2: National data of selected countries on carbon sequestration (in forests) and carbon storage in Harvested Wood Products and data on fellings.

3.1.2 Trade-off: Biodiversity and bioeconomy

3.1.2.1 Expansion of protected forests vs. wood use or contribution of forest sector to gross domestic product (GDP)

This trade-off is closely linked to the previous one. Intensive forest management practices for timber production can potentially impact other ecosystem services and functions. Trade-offs between ecological and economic interest in forests have been investigated in serval studies (Chen et al. 2016; Carpentier et al. 2017).

Table 3 illustrates national data of selected countries on expansion of protected forests, wood use via fellings in forests available for wood supply and standing roundwood quantities and the contribution of the forest sector to gross-value added (GVA). These predictors have been used as a proxy for the trade-off between conservation goals and bioeconomy goals, closely linked to section 3.1.1. Here, biodiversity goals are referred to by the share of protected forest area, assuming that protection status of forests limits, or prohibits wood extraction, thus potentially leading to less domestic wood supply. Fellings and roundwood quantities are used as a predictor for wood supply. The data on the ccontribution of forestry to gross value added (GVA) illustrates the macroeconomic importance and contribution of the forest sector to rural development (jobs, income, population and rural businesses).

Table 3: National data of selected countries on share of protected forest area, and fellings in forests available for wood supply and related indicators

CICES section	Resilience challenge RESONATE	System variable	Austria			Finland			Portugal			Resilience prediction (Positive Effect)	Data source
			2010	2015	2020	2010	2015	2020	2010	2015	2020		
Regulation & maintenance	Tackling biodiversity decline	Share of **protected forest area** of total forest area (%)	18.78	21.96	22.63	13.39	12.63	12.63	17.89	18.59	18.59	Increase of protected forest area is positive for the resilience of the forest ecosystems according to the 30% land protection requirements of the EU Biodiversity Strategy for 2030	UNECE INForest Database
Regulation & maintenance	Addressing changes in societal demand	Fellings in forest available for wood supply (m^3/ha)	7.1	7.1	n.a.	3.3	3.9	n.a.	n.a.	n.a.	n.a.	An increase is positive for the economic resilience of the wood-value-chain	FRA/Forest Europe database (3.1)
Provisioning	Addressing changes in societal demand	Roundwood – quantity (m^3/ha FAWS) (FE 3.2)	5.6	5.2	n.a.	2.5	3.0	n.a.	4.8	5.5	n.a.	An increase of the wood removals is important as a measure of the extent to which wood substitutes carbon-intensive materials, like steel and concrete.	FRA Forest Europe data-base (3.2)
Provisioning	Addressing changes in societal demand	Contribution of forestry (ISIC/NACE 02) to GVA (% of total GVA)	0.41	0.40	n.a.	1.68	1.83	n.a.	0.43	0.56	n.a.	An increase is positive for the economic resilience of the wood-value-chain	FRA/Forest Europe data-base (6.2)

A trade-off indication is visible for two out of three countries: In Austria the share of protected forest areas increased and the fellings remained stable, wood use as well as the contribution of forestry to GVA decreased. In Finland it was the other way round: The share of protected forest areas decreased (at least on paper, but most probably only due to different assignments) and then remained stable, whereas the fellings, the wood use and the contribution of forestry to GVA decreased. However, it is not obvious if the area of forest available for wood supply increased or if only the amount of fellings increased due to e.g. market-driven effects for example. In Portugal the data for all resilience predictors increased.

Regarding **biodiversity goals**, focus group participants´ perceptions of nature conservation vary. the implementation of ecological measures is connected with inherent difficulties, such as questions of geographical scale (e.g. habitat, forest stand, populations, landscape) and land-use (biodiversity impact of e.g. pastures that become forests). Participants highlighted that for effective biodiversity measures, a regional target state of biodiversity including monitoring indicators should be defined first and then worked towards. Furthermore, policies that have been developed on separate tracks as regards forests, need to be pulled together to a more coherent EU-forest policy framework, while any reconciliation of trade-offs needs to make sure that the public/affected communities are on board as well.

Besides the notion that strict protection should not be inflicted on most productive forest sites whenever possible, the participants favour integrated solutions to balance this trade-off. For example, some of the focus group experts highlight that nature protection must be a priority, but effective nature protection often requires active management, which again can be linked to wood provision in an integrated management system. These integrated approaches range from multi-purpose forestry, to close-to-nature forestry, or climate smart forestry. Such an integrated and optimistic view entails that increasing biodiversity leads to resilient forests which are the basis for potentially increasing consumption in the long run. Moreover, participants highlighted that the considerations of regional natural and market conditions are key for a holistic approach to building a bioeconomy.

However, the EU Biodiversity Strategy for 2030 (EC, 2020) request of putting 30% of the land area under protection and 10% of this share under strict protection could impact felling levels, the share of forestry in GVA and potentially increase the dependency of European countries on wood imports.

While the tables here cannot show future long-term effects, the importance of imports and exports has been highlighted several times and deserves closer inspection.

3.1.3 Excursus: Imports and consumption

This excursus is linked to the previous trade-off on the simultaneous increase in consumption and protection, as it is hypothesised, that wood imports would have to compensate for reduced harvest in the EU. The wording “consumption” refers to the available indicators on wood use: Consumption of industrial roundwood (1 000 m³ under bark), Consumption of sawnwood (1 000 m³) and Consumption of wood energy (1 000 m³).

As mentioned above, the inclusion of trade balances from wood imports and exports is crucial to allow several resilience indicators to be interpreted. For example, roundwood imports can compensate locally for systematically lower harvest levels, while maintaining timber processing levels, (resulting from policy framework conditions, see Del. 5.1. and 5.2).

Comparing the trends in table 4 for Austria, Finland and Portugal, no clear connection between the development of system variables on imports and consumption of wood commodities is visible. This might well be connected to an error in the available selection of resilience predictors here, since the consumption includes imports, making a reasonable comparison

impossible. Furthermore, a correlation between domestic harvest levels and imports depends on a plethora of factors, which does not allow us to identify a clear causation.

Since our model is clearly limited in its explanatory power, due to complex market interactions and data availability, we want to use this example to highlight a central point from the focus group discussions with stakeholders. The column “positive effect” in tables 2-4 serves as a reminder on what trend we will perceive as a positive effect for resilience pertaining to a specific resilience challenge. The focus group participants highlighted several times that perceptions vary on what is beneficial for resilience, depending on a particular challenge.

For instance, an increase in imports of forest products is perceived as having a positive effect on resilience, addressing changes in societal demands. However, this perception varies according to overall harvest levels, present infrastructure and the consideration of leakage effects. One stakeholder pointed out that under certain circumstances, imports can also have negative effects on overall resilience, depending on forest conditions and the present industrial infrastructure setting.

Furthermore, an increase in wood consumption, be that industrial roundwood, sawnwood, or wood for energy, was perceived by the stakeholders as being “fostering for strengthening resilience”. But other stakeholders, which connected lower wood consumption with increased areas for protection and biodiversity benefits (e.g. increased deadwood amounts, increased fire risk) pointed out that this can also be perceived as disadvantageous for resilience challenges such as biodiversity decline.

How resilience predictors are interpreted in the end, or in other words, “what is perceived as being beneficial for resilience” varies not only across stakeholders but will also vary with the extent of trade-off effects in the future.

Table 4: National data of selected countries on imports and on consumption

CICES section	Resilience challenge RESONATE	System variable	Austria			Finland			Portugal			Resilience prediction (Positive Effect)	Data source
			2010	2015	2020	2010	2015	2020	2010	2015	2020		
-	Addressing changes in societal demand	Imports of forest products (in Mil. USD)	3575.4	3357.9	3426.0	1480.1	1069.9	1174.8	1299.8	1248.6	1484.8	The value of wood-based forest products (roundwood, sawnwood, panels, pulp, paper) imported into a country is an indication of reliance on external sources of forest products.	UNECE INForest Database
-	Addressing changes in societal demand	Consumption of industrial roundwood (1 000 m³ under bark)	20367	19589	22929	51192	56438	60828	8903	12495	14522	An increasing amount (i.e. domestic production plus imports, minus exports) of unprocessed wood (logs) consumed by manufactur-ing industries, to make processed products such as construction timber, wood pulp, plywood, fur-niture and wooden fencing is an indication of increasing size of the domestic wood-processing industry and increases the resilience to changes in societal demands	UNECE INForest Database
-	Addressing changes in societal demand	Consumption of sawnwood (1 000 m³)	5277	5339	6253	4262	3186	3015	957	949	912	An increase in the consumption of sawnwood, used mainly in construction, increases the resilience to changes in societal demands.	UNECE INForest Database
-	Addressing changes in societal demand	Consumption of wood energy (1 000 m³)	19958	23606	24569	30111	37821	41492	n.a.	17645	17645	An increase in the consumption of wood that is used for energy, which is often used directly as heat but may include wood to make electricity, increases the resilience to changes in societal demands.	UNECE INForest Database

4. Conclusions: Synergies and Balances of Trade-offs

The national data presented above are showing specific short-term trends on identified potential trade-offs across countries. Carbon stocks in forest biomass are increasing or remain the same (table 2) for all countries analysed here. Also, the shares of protected forest area are increasing or remain the same (table 3). In addition, forest area and growing stock are also increasing (Forest Europe Data base). In the same time period, industrial roundwood consumption is also increasing, which leads to the conclusion that there is no trade-off between protection and wood consumption (yet) appearing from the available data. This might change in the future, due to new policy measures and if forests become increasingly affected by disturbances due to climate change. Actual fellings appear to have remained the same as well (table 2), but the data is poor, and the rising consumption figures are depending on imports as well (Cazzaniga et al. 2021). With this in mind, the current figures do not mirror the identified trade-offs at this point in time. Forest biomass stock has increased over the last decades despite an increase in the level of harvest, which is possible due to harvests remaining below the annual increment, and therefore allows increasing both the economic utilisation and other ecosystem services (see table 2).

The stakeholders in our focus groups during the RESONATE stakeholder workshop emphasised that integrated approaches like close-to-nature forestry, incentivised thinnings, multi-structural forest management, or other active and integrated management approaches should be used to create synergies and fill up the various demands like carbon sequestration, natural sinks, products, biodiversity and resilient forests. Regarding trade-offs along the value chain, the stakeholders wanted to foster discussions in an integrated way with all the actors. It has been found in our discussions, that the perception of specific trade-offs, namely the values attributed to forest protection or wood use is key.

Nowadays, the establishment of **mixed species stands** are regarded as a synergies and common measures to adapt forests to climate change, increase biodiversity and to increase technical resilience (Knoke et al. 2008, Schütz et al. 2006, Seidl et al. 2011, von Lüpke et.al. 2004). They are in line with the objective of “Climate Smart Forestry” (CSF) that “builds upon three main objectives; (i) reducing and/or removing greenhouse gas emissions; (ii) adapting and building forest resilience to climate change; and (iii) sustainably increasing forest productivity and incomes” (Nabuurs et al. 2017).

What might be overlooked is that there appear **more balancing needs** with the different objectives. For example, **silvicultural adaptation measures for building forests resilient to climate change may stay in conflict with measures of climate change mitigation and/or increasing productivity** (see Harmon & Marks 2002, Seidl et al. 2011). There is a need to consider **synergies and trade-offs between the market services and the non-marketed or not-directly marketed services by including the costs and benefits for the various stakeholders, including producers, consumers and other users** (Jacobsen and Hanley 2009). As Duncker et al. (2012) phrase it: “In accordance with the desired level of achievement, an integrative approach will synergistically best maintain biodiversity while providing the highest economic result. It raises rather more the question—**which attribute level is to be maintained while providing income from timber production**.” (ibid., p.14) The bundle of literature dealing with modeling the trade-off between maximum volume production and the maintenance of biodiversity at stand level (Hunter 2001, Boscolo and Vincent 2003, Gamborg and Larsen 2003) does not come to a unified conclusion. Yet, some claim that on the long run, low-intervention forestry, targeted to produce less volume but of high quality, results in the highest (economic) interest rates from timber production (Duncker

et al. 2012, p.12). This is convincing, when considering that the total value generated by a forest consists of wood *and* non-wood goods and services (Glück 2002, Weiss et al. 2004).

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