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Alpine Space

Forest EcoValue

Interreg Alpine Space Programme 21-27

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

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

Project ID: ASP0100005

Interreg
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D.1.3.1 Working Group ECO - Report

D.1.3.1

RESPONSIBLE PARTNERS:
PP2 - LOMBARDY FOUNDATION FOR THE ENVIRONMENT
PP8 -UNIVERSITY OF GRAZ, INSTITUTE OF ENVIRONMENTAL SYSTEMS SCIENCES

List of the Forest EcoValue project partners

PP1	Finpiemonte SpA – Regional financial and development agency / **Coordinator** [FINPIE]
PP2	Lombardy Foundation for the Environment – Fondazione Lombardia per l'Ambiente [FLA]
PP4	National Research Institute for Agriculture, Food and Environment – Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement [INRAE]
PP5	Slovenia Forest Service – Zavod za Gozdove Slovenije [ZGS]
PP6	Institute for Environmental Planning and Spatial Development GmbH & Co. KG – Institut für Umweltplanung und Raumentwicklung GmbH & Co. KG [Ifuplan]
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PP9	Regional Centre for Forest Property Auvergne-Rhône-Alpes – Centre Régional de la Propriété Forestiére [CNPF]
PP10	The French National Forest Office – Office National des Forêts [ONF]
PP11	Hozcluster Steiermark – Woodcluster Styria [HCS]

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Summary

Glossary

In the following section, a brief glossary is provided, offering some preliminary concepts for the discussion on the topic, which will be revisited throughout the report.

Business model and market

A business model refers to the way a company creates, delivers, and captures value. It outlines how a company operates, generates revenue, and sustains itself. It includes elements like revenue streams, cost structures, customer segments, and distribution channels. Essentially, a business model explains how a company does business. Within the context of forest ecosystem services (FES), a business model outlines how the entities engaged in a particular ecosystem shape their value architecture derived from FES-related activities. On the other hand, a market is the environment in which buyers and sellers interact to exchange goods or services. It includes the target customers or segments, competitors, and the broader economic, social, and cultural factors that influence buying and selling. A market is the space where business models are put into action.

In essence, a business model is the strategic plan for a company, while a market represents the context or space in which the business model operates. Understanding the market is essential for developing and adapting a successful business model.

Social value of ecosystem service

Environmental eco value is the value attributed to ecosystem services based on its contribution to the environment. It can be estimated by quantifying the benefits that ecosystems provide, such as carbon sequestration, and water filtration. An example could be the economic value placed on a wetland for its role in flood prevention, water filtration, and biodiversity preservation.

ESS market

Forest ecosystem services represent the various benefits that forests provide to both humans and the environment. These services can be classified into four categories: provisioning, regulating, supporting and cultural. FES markets create an environment where these services can be traded, driving conservation and sustainable management, addressing environmental issues, and fostering economic opportunities. Within this framework, these services are assigned an economic value to enable stakeholders to purchase, sell, or exchange them. For example: a water-providing company might pay a landowner to maintain a forest that filters water upstream from its treatment plant; a government might offer tax breaks or subsidies to landowners who manage their forests for timber production and other ecosystem services.

Externalities

Externalities refer to the unintended side effects or consequences of an economic activity that affect third parties who are not directly involved in the activity. Negative externalities occur when the side effects impose costs on others, such as pollution from a factory impacting the health of nearby residents. Positive externalities, on the other hand, occur when the side effects benefit others. One example of forest ecosystem services is carbon sequestration, which occurs when a forest is growing for timber.

Payment scheme

A payment scheme is a system for exchanging money or other forms of value for goods and services. It defines the rules and processes for how payments are made, including the types of payment methods accepted the timing of payments, and the fees associated with transactions. A payment for ecosystem services (PES) scheme involves a system where individuals or entities pay landowners to preserve or enhance specific ecological services provided by ecosystems such as forests. An example could be a PES program that compensates landowners for providing specific ecosystem services such as carbon sequestration, biodiversity conservation, watershed protection, soil erosion control, and recreational opportunities.

Public Good

A public good is a type of good or service that is non-excludable and non-rivalrous in consumption. This means that once provided, it is difficult to exclude individuals from using it, and one person's use does not reduce its availability to others. The main problem public goods pose to markets is the issue of free-riding, where individuals may benefit from the good without contributing to its provision, leading to under-provision by the market due to the inability to capture the full value of the good through traditional market mechanisms.

Replacement costs

Replacement costs are the expenses associated with replacing worn-out or obsolete assets. In FES context, it can indicate the cost associated with restoring or compensating for the loss of natural resources or ecosystem services.

1. Introduction

Forests are a crucial part of our planet's ecosystems, providing numerous essential services (forest ecosystem services - FES) that sustain human life and wellbeing. The ones included in our analysis for Forest EcoValue are provisioning (such as biomass, raw materials, and chemicals), regulating and maintenance (such as biodiversity, natural risk reduction, and CO2 absorption), and cultural (such as recreation and habitat experience) services. However, despite their immeasurable worth, forests all over the world are facing threats due to climate change and land degradation. Climate change is a significant threat to the stability and resilience of forest ecosystems. It alters temperature and precipitation patterns, increases the frequency of extreme weather events, and intensifies them. Additionally, land degradation caused by factors such as deforestation, soil erosion, and urbanization further weaken the ability of forests to provide their crucial services.

These challenges are becoming increasingly difficult due to the rising cost of maintaining forests. As the need for conservation and restoration efforts grows, the financial burden on local governments and forest owners is increasing. Furthermore, revenue streams from traditional activities like logging and timber production are no longer enough to cover these mounting costs. To address these pressing issues, there is a strong argument for creating forest ecosystem service markets (FES markets) along with robust business models (BMs). By recognizing and valuing the diverse range of services the forests provide, FES markets offer a framework for incentivizing their conservation and sustainable management.

In the context of the fragile Alpine ecosystem, where the impacts of climate change are particularly acute, FES markets can unlock new opportunities for sustainable land use and resource management in the region, while diversifying revenue streams beyond traditional wood value chains. These markets can channel additional resources towards initiatives aimed at mitigating climate change impacts, conserving biodiversity, and preserving critical ecosystem functions.

For the reasons explained, this report represents the first version of the economic valuation of FES and identifies the conditions for efficiently developing FES markets and business models. The report results from the work conducted by the Working Group ECO of the Forest EcoValue project and their continuous exchange with the Working Group BIO and Living Labs coordinators during bilateral and multilateral coordination meetings.

The first objective of this report is to introduce theoretical and foundational concepts that are necessary for framing the valuation of forest ecosystem services and the introduction of markets. By establishing a robust theoretical framework, the report seeks to highlight the values of these services. In addition to the theoretical groundwork, the report also addresses the aspects of conducting the valuation of FES and creating markets. This comprehensive report is intended to serve as a guide for the application of these methodologies within Living Labs. Partners and specifically Living Labs coordinators have been actively involved in the production of data, contributing their expertise and resources to ensure its accuracy and relevance. In the next phase of the project, project partners will play a crucial role in stakeholder engagement and further data collection within the Living Labs. This phase will involve working closely with local communities, policymakers, and other stakeholders to gather additional insights, validate the findings, and refine the market models.

2. Valuation of forest ecosystem services

According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), “the values of nature are representations of what people and society care about and what they consider important in relation to nature” (IPBES, 2022, p. 8). Understanding how nature and ecosystem services are valued, and by whom, facilitates improved governance and decision-making in conservation policies and related innovations. Assessing the social value of forest ecosystem services (FES) in the Alpine Space is crucial for designing sustainable and innovative business models, as well as circular, green, and bio-markets and forest-based value chains. This not only helps provide economic markers for potential payment schemes and identify primary beneficiaries of FES but also raises awareness among decision-makers about the overall social value of forests. In the following section, an overview of economic valuation methods is provided, to set out the base for the next two chapters, which describe in detail two valuation methods developed for the Forest EcoValue project – direct value transfer and robust optimization model.

Economic valuation approaches and methods

A variety of valuation methods have been developed to address a wide range of socio-ecological contexts and decision-making purposes in which valuation is conducted. IPBES defines five broad types of nature valuation: economic, biophysical, socio-cultural, ILK/Holistic, and Health valuation (IPBES, 2015). While not diminishing the relevance and importance of either of those, this section focuses on the classification of **economic valuation** (also called monetary valuation) of ecosystem services[1].

Some of the most used valuation approaches, respective methods, and associated challenges are presented in Table 1. It is important to remember that the choice of a method depends not only on the reasons behind evaluation but also determines the resulting value and possible range of its use. Table 2 further illustrates this range based on the valuation spatial scale and desired precision. More details on the criteria for selecting different approaches are provided in Table 3. Finally, Figure 1 lists the major requirements for their application.

Table 1. Most common economic valuation approaches and methods. Adapted from: Farber et al. (2002), Harrison et al. (2018), Termansen et al. (2022), Turner et al. (2016) and Velasco-Muñoz et al. (2022).

Approach	**Definition**	**Methods**	**Main challenges**
Direct market value, or price-based	Values are directly obtained from what people pay for the service or good based on prices on the market	Market price, payment for ecosystem services, net factor income, or cost of hunting permit	1) Requires conceptual and empirical understanding of the relationships between behavior, nature, and its contribution to well-being; 2) Challenging to reveal in-depth understanding of motivations behind behavior; 2) Allows to elicit mostly instrumental values of nature.
Revealed preference	Values are revealed indirectly through purchases or behavior	Travel-cost method: Estimated based on total amount of costs that the visitors incur when making visits to a particular place where they use the valued ES and/or their willingness-to-pay for the use of these services. The ES value is estimated by calculating the surplus, which is the difference between the obtained willingness-to-pay and the costs incurred to receive the service.	
		Production function: Used for those ES related to products that have a market of reference in which they are sold when the production of one is related to the availability of the	

[1] Refer to Termansen et al. (2022) for further information on other types of nature valuation.

Approach	Definition	Methods	Main challenges
		other. This relation is used to calculate monetary value by multiplying the marginal amount of a marketable product obtained from the ES by the market value of this product.	
		Hedonic pricing: Estimated based on what people will be willing to pay for the service through purchases in related markets, such as housing markets.	
Cost-based	Values are estimated based on the costs of mitigation actions to avoid, minimize, restore, or replace ecosystems and their services.	Avoided damage cost, restoration cost, replacement cost, social cost of pollution or carbon	
Stated preference	Values are derived from individual respondents stated hypothetical choices regarding change in the utility associated with a proposed increase in quality or quantity of ES	Contingent valuation or choice experiment	1) Concern about reliability of statements; 2) Power disparity can reduce the validity of group-based methods; 3) representativeness in selection of respondents.
Value transfer	Values are transferred from existing studies (study site) to a new context (policy site)	Unit and adjusted unit value transfer: Transfer of a simple, unadjusted value or a value adjusted according to observable attributes of the policy site	1) Limited validity due to the differences between sites; 2) Transfer errors; 3) Poor quality and low accuracy of primary studies and data.
		Function and meta-analytic function transfer: Transfer of value based on the function drawn from various sources including individual studies or meta-analysis of data from multiple studies	

Note that the presented list of approaches and methods applied for monetary valuation is not exhaustive. Further information can be found in Harrison et al. (2018) and Jacobs et al. (2018).

Table 2. Range of uses for ecosystem service valuation. Source: Costanza et al. (2014).

Use of valuation	Appropriate values	Appropriate spatial scales	Precision needed
Raising Awareness and interest	Total values, macro aggregates	Regional to global	low
National Income and Wellbeing Accounts	Total values by sector and macro aggregates	National	medium
Specific Policy Analyses	Changes by policy	Multiple depending on policy	medium to high
Urban and Regional Land Use Planning	Changes by land use scenario	Regional	low to medium
Payment for Ecosystem Services	Changes by actions due to payment	Multiple depending on system	medium to high
Full Cost Accounting	Total values by business, product, or activity and changes by business, product, or activity	Regional to global, given the scale of international corporations	medium to high
Common Asset Trusts	Totals to assess capital and changes to assess income and loss	Regional to global	medium

Table 3. Criteria for selecting different approaches. Adapted from: Harrison et al. (2018).

Criterion	Source of data: Primary study	Source of data: Value transfer	Valuation approaches: Stated preference	Valuation approaches: Revealed preference	Valuation approaches: Direct market value and cost-based
Explorative – Method development	Green	Yellow	Green	Green	Green
Informative – Awareness raising	Yellow	Green	Yellow	Yellow	Green
Informative – Asset accounting	Yellow	Green		Yellow	Green
Decisive – Priority-setting	Yellow	Green	Green	Yellow	Yellow
Technical – Incentive design, pricing	Yellow		Green	Grey	Yellow
Technical – Litigation/Fines	Grey		Grey	Grey	Yellow
Addresses multiple ecosystem services	Yellow	Yellow	Yellow	Yellow	
Enables trade-offs to be explored	Yellow	Yellow	Green	Green	
Stakeholder participation			Yellow	Grey	
Incorporates local knowledge			Green		
Easy to communicate	Green	Yellow	Green	Yellow	Green
Transparent (process easy to understand)	Green	Yellow	Yellow	Yellow	Yellow
Integrated treatment of issues			Green	Yellow	Yellow
Integration across disciplines			Green		
Integration of processes (with governance)			Yellow	Grey	Green
Integration of spatial scales (cross-scale)			Grey		
Integration of temporal scales (cross-scale)			Grey		
Spatially-explicit			Yellow	Green	Grey
Temporally-explicit			Green	Green	Green
Requires time series data				Green	Yellow
Mainly quantitative data	Green	Green	Green	Green	Green
Mainly qualitative data					
Addresses uncertainty	Green	Yellow	Green	Green	Yellow

Green: a key feature; yellow: a possible feature / some importance for method selection; grey: a rare feature.

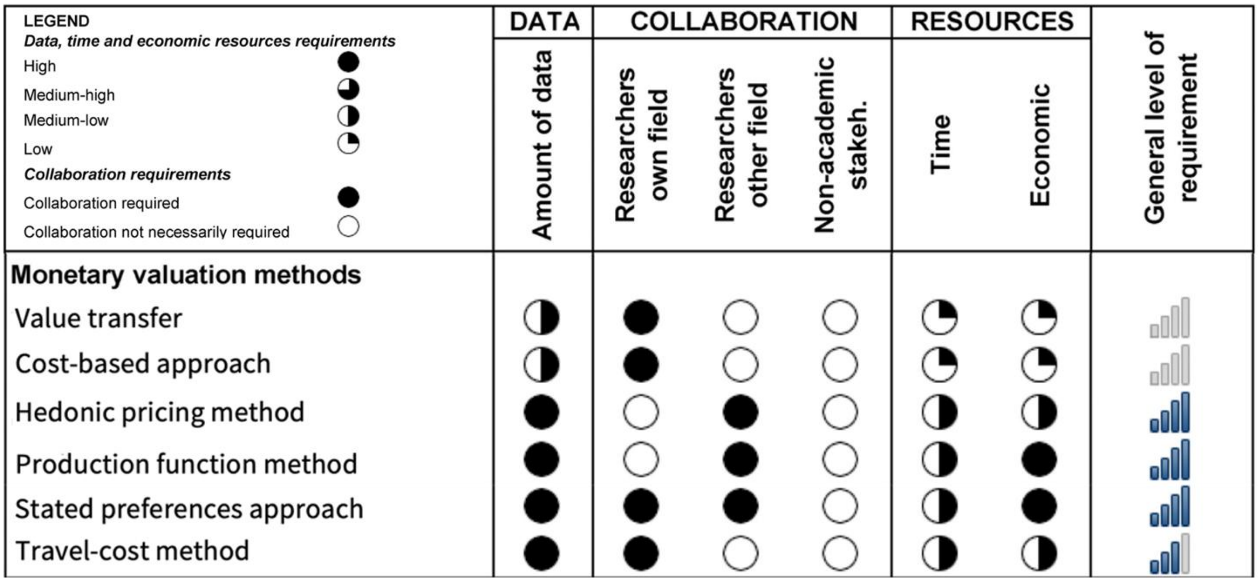


Figure 1. Methodological requirements for economic valuation approaches and some methods. Adapted from: Harrison et al. (2018) and Jacobs et al. (2018).

Methods were assessed according to the level of requirements in terms of data, time, and economic resources. The general level of requirements is indicated by the 'wifi signal' bars and was estimated by summing the scores of (1) the need for new data, (2) the need for collaboration with scholars from other disciplines and with non-academic experts, and (3) the level of time and economic resources for applying each method. Full 'wifi signal' bars indicate the highest requirements, and empty 'wifi signal' bars indicate the lowest requirement to apply a particular method.

Unit value transfer based on the economic valuation studies conducted in Europe

As defined in the previous section, the value transfer approach allows for estimating an approximate value for the policy site (to put it in the context of the Forest EcoValue project, for the national Living Labs) based on already existing valuation studies (see D.1.3.2_Database-of-FES-values_Europe.xlsx).

This method was chosen due to its relatively low methodological requirements (Figure 1), and its ability to simultaneously cover all national Living Labs, address multiple ecosystem services, and explore potential trade-offs. As this method produces an economic value of relatively low precision, the valuation exercise serves strictly informative and communicative purposes and supports priority-setting (Tables 1 - 2). If elicited value sparks an interest in a specific FES or a FES bundle, Living Labs' coordinators are invited to refer to the previous section to choose a methodology for a subsequent primary study.

Methodology and data collection

A value transfer study of European forests conducted by Grammatikopoulou & Vačkářová (2021) was selected as a methodological foundation for the current study. They conducted a review (direct value transfer) and a meta-regression analysis (statistically adjusted value transfer) of monetary valuation studies of European forests ES, published between 2000 and 2017. Their database of studies was supplemented by the most recent valuations searched in Scopus and ISI Web of Knowledge and Ecosystem Service Valuation Database (ESVD), extracted in June 2023. Search strings and search results are reported in Table 4. Grey literature and reports were not excluded from the search. Studies were searched in English; however, this limitation was lifted in the ESVD database as all the main information on valuation was provided in English.

To be included in the database, the valuation study had to fulfill the following screening criteria:

- Only primary monetary valuation studies;
- A final, average or at least a range of monetary values must be provided;
- Present or past values based on the real context must be available[2];
- Studies should have no apparent errors in methodology and calculations.

Table 5 presents the selected studies and the number of value observations per study.

After screening the primary studies, the database of the ecosystem value observations was compiled according to the template presented in Table 6. A common challenge of value transfer studies is inconsistency in the ES value reporting in the primary studies, which is often dependent on the ES under assessment as well as the method of choice. Therefore, some value transformations were necessary and were performed as described in Table 6. Moreover, some information about the study sites was missing in the primary studies and was subsequently compensated with the data from external sources, which is additionally specified in Table 6.

[2] Values estimated by future scenarios were deemed unacceptable as they are based on the set of assumptions.

Table 4. Results of a literature search and review.

Database	Keywords	Timespan	No of studies identified	No of potentially relevant studies	No of relevant studies	Total number of studies included[3]
Scopus	"ecosystem service" AND "forest" AND "valuation" AND "Europe" "ecosystem" AND "service" AND "forest" AND "valuation" + EXCLUDE non-European countries	Published after 2017	332	76	17	29
Web of Science	"ecosystem service" AND "forest" AND "valuation" AND "Europe"		67			
ESVD	forest ecosystems + Europe		8			

Table 5. Studies and the number of value observations per study included in the literature review and analysis.

Study number	Study reference (Authors, publication year)	Country	Year of valuation	No of observations
1	Hein, 2011	Netherlands	2007	7
2	Caparrós et al., 2017	Spain	2010	1
3	Goio et al., 2008	Italy	2002	8
4	Häyhä et al., 2015	Italy	2010	9
5	Meyerhoff et al., 2012	Germany	2009	1
6	Matero & Saastamoinen, 2007	Finland	2000	10
7	Paletto et al., 2015	Austria	2012	6
8	Sisak et al., 2016	Czech Republic	2010	1
9	Gołos, 2009	Poland	2000	6
10	Grilli et al., 2015	Italy	2015	9
11	Getzner et al., 2017	Austria	2016	2
12	Brey et al., 2007	Spain	2006	4
13	Bastian et al., 2017	Germany	2017	8
14	Olschewski et al., 2012	Switzerland	2011	1
15	Ezebilo, 2016	Sweden	2007	1
16	Termansen et al., 2013	Denmark	2011	1
17	Pechanec et al., 2017	Czech Republic	2015	2
18	Accastello et al., 2019	Italy	2018	1
19	Corona et al., 2018	Italy	2016	1
20	Ehrlich, 2021	Estonia	2021	9
21	Enríquez-de-Salamanca, 2023	Spain	2020	20
22	González-Díaz et al., 2019	Spain	2019	2
23	Marnasidis et al., 2021, June	Greece	2018	12
24	Drin Corda	North Macedonia	2018	1
25	Ivanova et al., 2016	Bulgaria	2020	1
26	Broadmeadow et al., 2018	United Kingdom	2018	1
27	Hájek & Vrabcová, 2020	Czech Republic	2020	5
28	Marini Govigli et al., 2019	Spain	2014	6
29	Makrickas et al., 2023	Lithuania	2022	2

[3] Including the studies from the original database by Grammatikopoulou & Vačkářová (2021). However, some of them were deemed irrelevant due to their quality and/or valuation method used and removed from the dataset of the current study. For the same reason, some value observations were removed, while some new value observations from the old set of literature were added to the database.

Table 6. Template of the database of the ecosystem services value observations.

Sections	No	Column	Inputs	Type	Explanation and transformations
Study info	1	A	ID (No of observation)	n/a	Unique number of an individual FES value
	2	B	Study ID	n/a	Unique number of an individual valuation study
	3	C	Authors	DR	-
	4	D	Year of publication	DR	-
	5	E	Reference	DR	DOI or a link to the study
Site and country specifics	6	F	Site description	DR	Details about the area undergoing valuation
	7	G	Country	DR	Country where economic valuation was conducted
	8				
	9	I	Area of site (ha)	DR	-
	10	J	Area of forest at national level (ha)	DR or SD[4]	Total area of forest at national level in a year of valuation
	11	K	Scale (1=Local, 2=Regional, 3=National)	ID	Scale of the valuation study was assigned as follows: 1. Local: cities, districts, municipalities, specific areas like parts, mountains, etc. 2. Regional: regional units in a country (region, province, federal land, etc.). 3. National: whole country.
	12	L	Protected area status (1=Yes, 0=No, Partially = 2)	DR or SD	An area was assigned a protected or partially protected status if the entire area is claimed to be protected or only part of it, respectively
	13	AL	Purchase power parity (PPP) conversion factor, GDP (LCU per international $) in a year of valuation	SD[5]	World Bank Databank development indicators according to the update on 19.09.2023
	14	AM	Consumer price index (2010 = 100) in a year of valuation	SD[6]	
	15	AN	Consumer price index (2010 = 100) in 2023	SD[7]	
Ecological and ecosystem services details	16	H	Area of forest at site level (ha)	DR, ID or SD[8]	If precise area not reported in the primary study, either estimated based on other data provided in the study or equaled to the area of forest at national level at the year of valuation when the study is on the national scale
	17	M	Biogeoregion	SD[9]	Assigned according to the site description according to the respective maps. If more than one biogeoregion/ecoregion/biome is in the designated territory, the dominant one was selected
	18	N	Ecoregion	SD[10]	
	19	O	Biome	SD[11]	
	20	P	Ecosystem service as reported	DR	-
	21	Q	ES section	ID	Classified according to CICES V5.1
	22	R	ES group	ID	
	23	S	ES class	ID	
	24	T	Short description	ID	Renamed (21) in a unified format

[4] For EU27: Area of wooded land. Eurostat. Accessible via link. Retrieved on 09.10.2025. For UK: Global Forest Resources Assessment 2020. FAO. Accessible via link. Retrieved on 09.10.2025.
[5] Retrieved from the World Bank Databank on 09.10.2025. Accessible via link.
[6] Ibid.
[7] Ibid.
[8] For EU27: Area of wooded land. Eurostat. Accessible via link. Retrieved on 09.10.2025. For UK: Global Forest Resources Assessment 2020. FAO. Accessible via link. Retrieved on 09.10.2025.
[9] Biogeographical regions, Europe 2016, version 1. Accessible via link.
[10] Ecoregions2017©Resolve. Accessible via link.
[11] Ibid.

Sections	No	Column	Inputs	Type	Explanation and transformations
	25	U	Thematic group	ID	Short descriptions of ES were thematically grouped to increase the number of value observations per group
Valuation details	26	V	Economic value 1 (value/ha/year)	DR	-
	27	W	Economic value 2 (value/person or household or visitor/ha/year)	DR	-
	28	X	Economic value 3 (value/tonnes of CO_2/year)	DR	-
	29	Y	Economic value 4 (value/year)	DR or TD	If not reported in the primary study and is necessary for calculating 27, calculated in one of the following ways, depending on what data was reported or could be supplemented from other sources and/or estimated implicitly, and simultaneously accounting for methodological specifications of each primary study: • (27)*(33) • (27)*(34) • (27)*(35) • (30)*(36) • (28)*(37)
	30	Z	Economic value 5 (value/visit)	DR	-
	31	AA	Currency	DR	-
	32	AB	Year of Valuation	DR or ID	If not reported in the primary study, the study submission year was assumed as a valuation year
	33	AC	Local population	DR	-
	34	AD	No of households	DR or SD	Where applies, sources specified in the database in the Comments (XX)
	35	AE	No of visitors/year	DR or SD	Number of visitors or permit holders at the study site
	36	AF	No of visits/year	DR	Number of visits at the study site
	37	AG	CO_2/year	DR	Total carbon sequestered or stored (tonnes/year) on site in year of valuation
	38	AI	Transformation of values in value/ha/year	DR or TD	If not reported in the primary study in the format of value/ha/year, the value was transformed the following way: (30)/(8)
	39	AJ	Method	DR	See Table 1
	40	AK	Approach	ID	
	41	AO	CPI 2023/CPI year of valuation	TD	Calculated the following way: (17)/(16)
	42	AP	Value in local currency in 2023 (value/ha/year)	TD	Calculated the following way: (36)*(40)
	43	AQ	Value in constant prices 2023 (international $) (value/ha/year)	TD	Calculated the following way: (39)/(13)
Other	44	AH	Comments	ID	Relevant comments on input

DR: Data as reported in the primary study; ID: Implicit data from the primary study; SD: Supplementary data from another dataset; TD: Transformed data
For No XX-XX where primary studies did not directly report data, supplementary data was searched only when it was necessary for calculation of 27 and subsequent value transformation.

Database of economic values of FES in Europe: direct value transfer

Overall, 138 observations are included in the value database. Most of them are the economic values of the regulating FES (Figure 2).

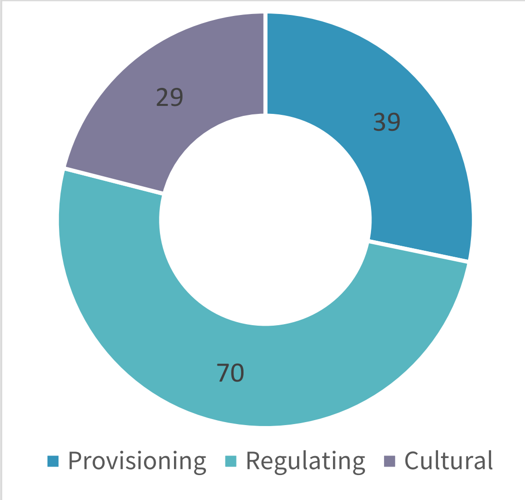


Figure 2. Representation of different ES sections (number of value observations) in the monetary valuation studies of FES in Europe

The FES thematic groups as well as their mean values and standard deviations are presented in Table 7. Additional mean values of each thematic group calculated based on the method demonstrate some variability in values for every FES implied by the methodological assumptions. Moreover, Table 7 contains mean values of FES for the Alpine biogeographical region and each of the Project Partner countries. Most of the FES thematic groups were assessed for the Alpine biogeoregion. FES that were pre-selected for the Living Lab in Italy Italian FES are the most represented in the values database, however, with a dominance of the provisioning ES, which is a common trend among other countries of project partners. Note, that none of the studies performed monetary valuation for the FES in France. However, economic values of FES pre- selected for the Living Lab in France are available in studies and reports in national language (Chevassus-Au-Louis & Pirard, 2011; Ministère de l'Écologie, 2023).

Table 8 provides further information about the forest types present in the database according to the different classifications (more details in Table 6). Regarding the approaches applied in the monetary valuation studies, the cost-based approach was used for most value observations in the database (Figure 3). Further descriptive statistics on the values of FES in Europe are provided in the database (see "Overlook").

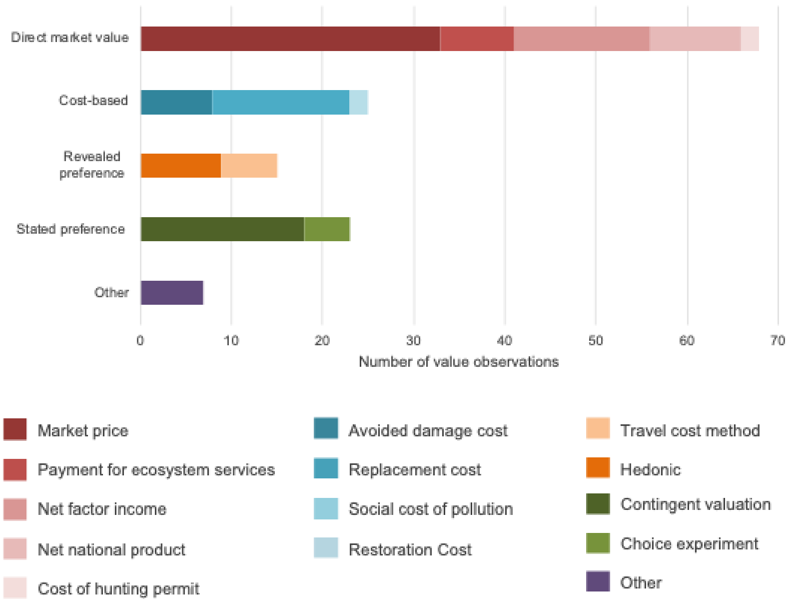


Figure 3. Economic valuation approaches and methods applied in the FES valuation studies in Europe

Table 7. Mean economic values of FES in Europe in constant prices 2023 (international $/ha/year).

FES thematic groups	N*	*Mean*	*Std. Dev.*	Evaluation approaches					Alpine**	PP countries***			
				DMV	RP	CB	SP	OT	biogeoregion	IT	AT	DE	SLO
						Provisioning							
Timber	11	*161.80*	*186.48*	161.80					226.07	190.24	635.10	8.10	91.83
Fuel- and firewood	7	*79.36*	*142.98*	79.36					104.17				
Other wood forest products	2	*3.57*	*4.36*	3.57					6.65	6.65			
Mushrooms	4	*10.70*	*19.00*	39.19	1.20				13.79	39.19			
Game	5	*26.13*	*24.12*	26.13					33.72	19.24			
Water	2	*370.35*	*351.95*	121.48		619.21			121.48	121.48			
Other non-wood forest products	9	*24.78*	*55.20*	31.41			1.55		51.61	12.54	168.80		
						Regulating							
Air quality maintenance	2	*14.6299232*	*16.06*				14.63						
Carbon sequestration	17	*3,246.75*	*12,041.48*	3,938.66		19.05	30.01	4.48	80.87	76.82	113.48	49,828.55	56.35
Carbon storage	1	*2,782.71*	*n/a*	2,782.71									
Water quality maintenance	19	*93.64*	*110.16*		87.93	728.03	251.60		803.89	676.39	895.07	3,892.86	1,344.12
Natural hazards protection	13	*644.19*	*986.40*	8,202.89			1.75						
Habitat maintenance	5	*66,021.72*	*130549.02*			164,258.47	530.55						
Climate regulation	7	*7.63*	*6.86*			107.47	10.67						
Pollination	2	*7,572.03*	*5888.37*				7.63						
Soil loss prevention	2	*6.13*	*5.61*				6.13						
						Cultural							
Recreation and tourism	10	*351.45*	*494.25*	368.40	763.40		50.16	9.39	1,213.75				
Non-recreation	8	*80.45*	*63.41*		122.35		4.75	22.30	7.73				
Leisure mushrooming	5	*9.92*	*13.09*	9.72	2.42		32.61		4.54	9.72			
Leisure hunting	4	*29.30*	*29.39*	32.10	20.90				18.55	18.55			

N: number of value observations; Std. Dev.: standard deviation; DMV: direct market value, or price-based approach; RP: revealed preference-based approach; CB: cost-based approach; SP: stated preference-based approach; OT: other methods.

* FES valuated as a mix of more than one thematic group were excluded from this calculation (e.g., air and water quality maintenance, leisure mushrooming and berry picking).

** In the present database, Alpine biogeoregion is represented in the studies conducted in Austria, Italy, Slovenia, Switzerland, Bulgaria, North Macedonia, Slovakia, and Spain.

*** No monetary valuation studies performed for the FES in France were identified

Table 8. Type of the forests included in the economic valuation studies in Europe.

Biome (N; mean value; Std. dev.)	Ecoregion	N	Biogeoregion	N
Boreal Forests/Taiga (11; 37.90; 53.63)	Scandinavian and Russian taiga	11	boreal	22
Temperate Broadleaf & Mixed Forests (57; 6965.08; 39675.19)	Sarmatic mixed forests	11		
	Pannonian mixed forests	6	pannonian	5
			continental	19
	Baltic mixed forests	1		
	Central European mixed forests	6		
	Western European broadleaf forests	20		
	Rodope montane mixed forests	1	alpine*	*
	Pyrenees conifer and mixed forests	4		
	Dinaric Mountains mixed forests	4		
	European Atlantic mixed forests	7	atlantic	8
	Celtic broadleaf forests	1		
Temperate Conifer Forests (28; 208.30; 385.49)	Alps conifer and mixed forests	24	alpine	43
Mediterranean Forests, Woodlands & Scrub (42; 2477.34; 4659.60)	Pindus Mountains mixed forests	1		
	Aegean and Western Turkey sclerophyllous and mixed forests	12	mediterranean	41
	Iberian conifer forests	2		
	Iberian sclerophyllous and semi-deciduous forests	23		
	Northeast Spain and Southern France Mediterranean forests	4		

N: number of total observations per ecoregion or biogeoregion.
*For presentation reasons, the number of observations for the studies conducted in the Alpine biogeoregion is given in the Temperate Conifer Forests rows.

The decision tree provides step-by-step guidance for searching monetary values relevant for the respective Living Labs in the database (Figure 4). Generally, there are two approaches for estimating a value proxy:

1) By ecosystem relevance ("yes" to the first question in Figure 3): Not all project partner (PP) countries are represented in the database, as well as not all FES were assessed for all the PP countries due to the unavailability of the studies; in that case, economic values and / or studies could be searched based on the ecosystem services of interest. However, when applicable, bio-geographical aspects could be integrated into the search strategy in the later stage (see below).
2) By geographical relevance ("no" to the first question in Figure 3): If the purpose of the assessment is getting an overview of general FES potential for a specific country, biogeoregion, ecoregion and / or biome, then a search based on the bio-geographical aspects could be performed. This requires identifying a forest type according to all or one of the classifications, as described in Table 6 (biogeoregion, ecoregion and/or biome). For the studies conducted on regional and local scales, it might be relevant to have a look at the site description, as there could be a study conducted directly in the area of the respective LL, close to it, or in a similar area.

As a result, a proxy value of a FES could be acquired, adjusted to the purpose of the assessment and/or to the bio-geographical context. This value could be used for communication purposes, identifying beneficiaries and potential trade-offs, as well as raising awareness about the FES potential in the area of the Living Lab. For a more precise value, it is recommended to perform a primary study with a method, most suitable to the purpose and the context of the assessment.

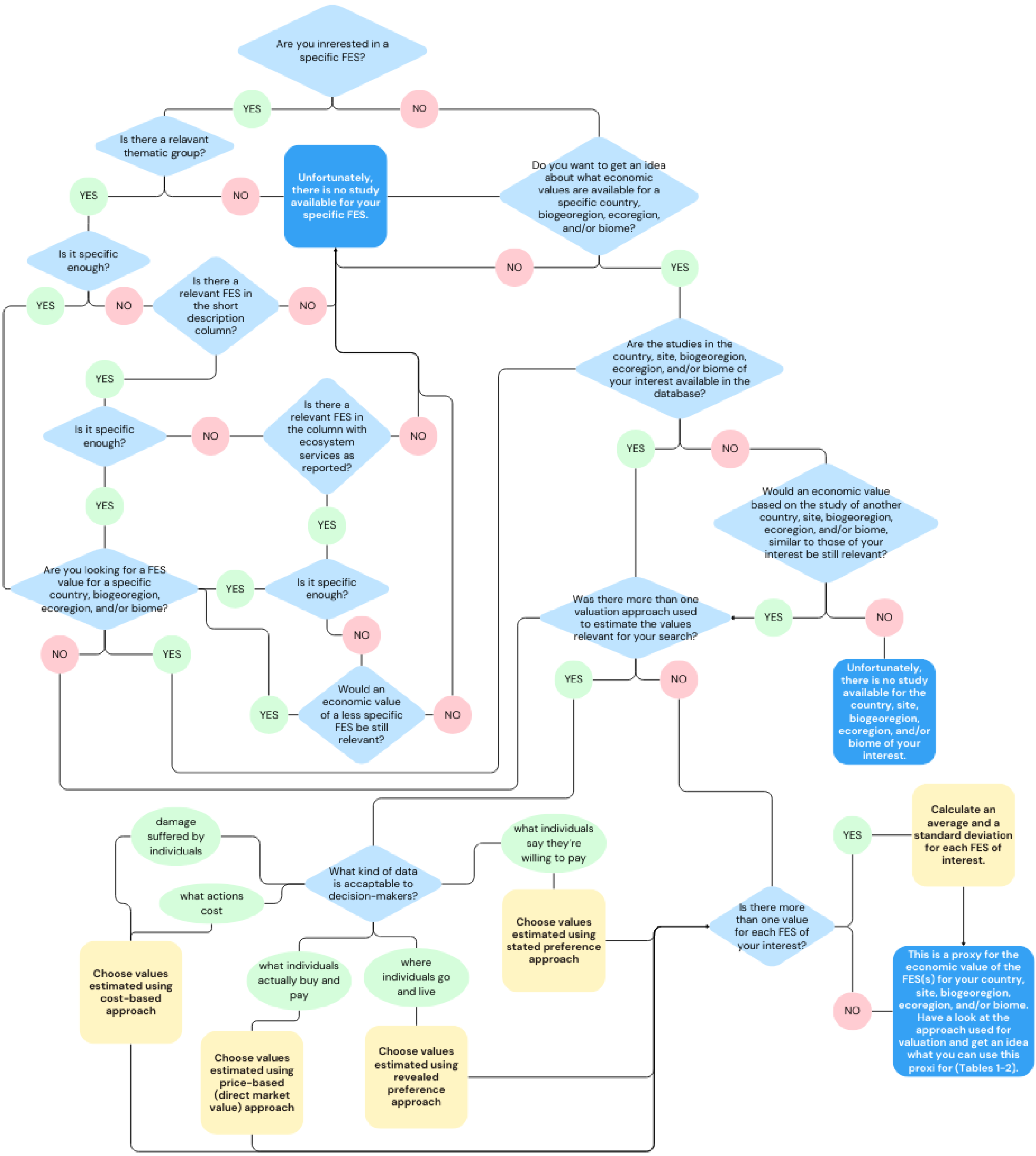


Figure 4. Direct value transfer decision tree. Partially based on: Harrison et al. (2018).

A multi-criteria approach to the provision of market and non-market FES

Private forest owners constitute an impressive proportion of forests in Europe – about 60% (Weiss et al., 2019; Živojinović et al., 2015). The share of non-industrial forest owners (NIPFs) as well as the forest holding size distribution varies from country to country. Nevertheless, large industrially owned holdings are uncommon in Europe, except in Sweden and Finland (Weiss et al., 2019). In Austria, privately owned forests constitute 81% of the forestland (BML, 2023) and more than half of them are held by small-scale forest owners (property size is less than 200 ha), while 75% of them own less than 20 hectares (Waldgeschichten, 2022). A similar trend is observed in France, where 75% of the forestland is private holdings and 62% of them are small-scale properties (1-4 ha) (Živojinović et al., 2015). 48% of German forests are under private ownership and more than 50% of them are smaller than 20 hectares with the average of around 2.5 ha (BMEL, 2022). Slovenian individual private forest owners hold 75% of the total forest owners (Živojinović et al., 2015). Private forest ownership share in Italy is in a similar range – 63.5% (Arma dei Carabinieri, 2015). Evidently, small-scale private forest owners are important actors in the successful implementation of any FES provision and conservation measures.

Simultaneously, economic literature shows that NIPFs are more prone to base their forest management decisions on multiple objectives (Garcia et al., 2018), which indicates their massive potential for the FES provision. Moreover, many studies across countries of the European Union have identified a lack of entrepreneurial or business thinking among forest owners (Živojinović et al., 2015), which may hinder the uptake of innovative circular/bio business models in the forest-based sector.

To design effective incentives and ensure the success of the Pilot Action, it is important to understand what factors play a role in the decision-making and what are the core management drivers of the forest owners. Studies pinpoint a mix of factors that play a role. Among those are structural characteristics of the property (e.g., forest size (Hatcher et al., 2013), forest composition, site quality, owners' socio-demographic characteristics (Beach et al., 2005), and the level of awareness of the forest owners regarding the capacity of their forests to provide different ecosystem services (Bjärstig & Kvastegård, 2016). There is further evidence that many private forest owners do not orient their management choices primarily based on the rationale of profit, particularly when enhancing or maintaining the provision of ecosystem services (Feliciano et al., 2017; Gatto et al., 2019; Juutinen et al., 2021). According to the case study by Gatto et al. (2019) conducted in the Italian Alps, profit generation was often relevant only in case of the owner's full reliance on income, which was a rare case. However, literature that investigates the motivation behind the NIPF forest management strategy with a focus on Alpine space is limited (Gatto et al., 2019).

To identify driving factors in the forest management decisions of the forest owners, we use a multi-objective, robust optimization model (ROM). This model is based on a version of goal programming – a continuous multi-criteria decision analysis (MCDA) technique coupled with a robust optimization approach to integrate uncertainty in the decision process (Knoke et al., 2015). MCDA allows for determining forest composition based on multiple criteria (hereafter, indicators, and objectives, i.e., a bundle of indicators). This way the diversity of factors influencing forest owners' decision-making could be represented. Finally, when compared to the actual forest composition, the hypothetical optimized forest could inform about the primary management objectives of the forest owners. Other scholars have already used ROM to identify implicit land-use management objectives in the context of agroforestry (Gosling et al., 2020; Reith et al., 2020).

Furthermore, the multi-objective, robust optimization model (ROM) integrates an uncertainty factor in the optimization process, allowing for the consideration of uncertainties associated with FES provision and potential risk aversion among forest owners (Knoke et al., 2016). Another advantage of the model is that it allows for the units of measurement of the performance indicators to be different, thereby addressing the problem of incommensurability of values and data scarcity issues. The robust optimization model is commonly applied in studies targeting multi-objective forest management (Chreptun et al., 2023; Friedrich et al., 2021; Reith et al., 2020; Uhde et al., 2017) or broader land-use management (e.g., agroforestry (Gosling et al., 2020; Reith et al., 2020) or forestry compared to agriculture (Jarisch et al., 2022; Knoke et al., 2014, 2016)).

Following multiple studies that have performed optimization based on the perceived data collected from experts (Chreptun et al., 2023; Reith et al., 2020; Uhde et al., 2017) or land owners (Chreptun et al., 2023; Gosling et al., 2020), the main input data of the ROM in the current project are the perceptions of the forest owners. However, minor adjustments to the needs of the Living Lab are possible (e.g., additional bio-physical or financial data). Combined with the bio-physical data on the FES performance in the areas of the Living Lab, this information could inform Living Lab coordinators in communication and participatory process strategy, as well as policy makers in the design of incentives and FES provision strategies.

Forest management objectives

To apply goal programming to forest management decisions, it is necessary to select objectives and indicators relevant to the forest owners. For the tool developed for this project, a dual approach is applied. As a first step, nine indicators[12] were pre-selected, i, in total based on previous surveys used in similar studies (Chreptun et al., 2023; Gosling et al., 2020; Reith et al., 2020), literature review, and expert consultation with the consortium (Table 9). The pre-defined indicators are grouped into three management objectives, market value, non-market value, and management complexity. A wide range of indicators will allow for the exploration of the preferred forest composition according to the preferences collected from the forest owners. As the second step, the implicit forest management objectives are derived based on the comparison of the actual forest composition and optimized variants.

Table 9. Description of the nine pre-defined indicators, *i*, against which forest owners will evaluate the six forest stand types.

Management objective	i	Indicator	Definition	Direction	Rational	References
Market value	1	Long-term income	Profit made by the forest owner over 20 years, including all possible revenue streams from the forest type (timber, fuelwood, non-wood forest products, commercial recreational activities, etc.)	More is better	Profitability is believed to be an important rationale for the forest management decisions	Chazdon et al. (2016); Gosling et al. (2020); Plevnik & Japelj (2023); Spinelli et al. (2017)
	2	Meeting household needs	The degree to which the forest type is able to provide materials and food needed in the household of the forest owner	More is better	Non-industrial forest owners may be constrained by the need to meet household needs	Gatto et al. (2019); Gosling et al. (2020)
	3	Liquidity	The extent to which the forest type provides frequent and regular income, including how easily the forest type can	More is better	Cash flow can be an important concern or constraint for the forest owners	Chazdon et al. (2016); Gosling et al. (2020); Reith et al. (2020)

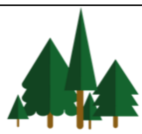
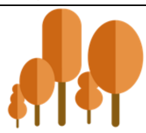
[12] Note that in the survey text, we opted for a "criterion" instead of an "indicator" to increase clarity of the questions and simplify the participation in the survey.

Management objective	i	Indicator	Definition	Direction	Rational	References
			be converted to cash if needed.			
Non-market value	4	Carbon storage and sequestration	The degree to which the forest type is able to sequester and store carbon	More is better	According to the preselection of FES relevant for the Forest EcoValue Living Lab areas	Chazdon et al. (2016); Chreptun et al. (2023); Gatto et al. (2019); Juutinen et al. (2022); Lombardo (2023); Riviere & Caurla (2021); Schaich & Plieninger (2013)
	5	Natural hazards protection	The degree to which the forest type is able to prevent natural hazards like avalanches, landslides, rockfalls, and floods	More is better		Chreptun et al. (2023); Dupire et al. (2016); Floris & Di Cosmo (2022); Lombardo (2023); Maroschek et al. (2015); Scheidl et al. (2020)
	6	Ecological functions of the forest	The degree to which the forest type is able to maintain its ecological functions, such as provision of soil, water and air quality, and habitat for wild plants and animals	More is better		Chazdon et al. (2016); Chreptun et al. (2023); Gatto et al. (2019); Juutinen et al. (2022); Lombardo (2023); Plevnik & Japelj (2023); Schaich & Plieninger (2013)
	7	General preference	Forest owners' preferences for each forest type as a proxy for cultural value of the forest	More is better	Proxy for additional cultural benefits of each forest type, to reflect less tangible, intrinsic values not captured by the other indicators	Ciesielski & Stereńczak (2018); Feliciano et al., 2017; Ficko et al. (2019); Gatto et al. (2019); Gosling et al. (2020); Lombardo (2023)
Management effort	8	Management complexity	The need for labor, special equipment, machinery, skills, and knowledge	Less is better	Increased management complexity, labor availability, and the need for specialized knowledge may represent a barrier to adopting a new forest management regime	Gosling et al. (2020); Spinelli et al. (2017)
	9	Management costs	The costs of establishing and maintaining the management regime for the forest type	Less is better	High costs of managing a forest type could pose a potential barrier to multifunctional and FES-oriented forest management	Gosling et al. (2020)

Direction refers the desirable state of an indicator.

The forest owners will assess the performance of six forest stand types, f, (Table 10) against each of these indicators. Adapted from Chreptun et al. (2023) based on the expert judgment of project partner (PP) 7, PP8, and PP5, these forest types were chosen as they cover all major forest and management systems in the Alpine forests, which in turn enables transnational comparability of evaluation results.

Table 10. Forest stand types. Adapted from: Chreptun et al. (2023).

Schematic visualization	***f***	**Forest stand type**
	1	Conifer, even-aged
	2	Conifer, uneven-aged
	3	Deciduous, even-aged
	4	Deciduous, uneven-aged
	5	Deciduous and conifer, uneven-aged
	6	Forests without intervention

Methodology

Box 1 provides a methodological outline for the application of the tool. Each step is further described in the following part of this sub-section.

Step 0.

Reasoned by the data scarcity issues, assessment of the forest composition as well as ownership structure in the study area is proposed as a preparatory step. This information will be relevant for the analysis performed in Step 3. Therefore, the assessment could continue with the survey data collection (Step 2). Data gaps that were impossible to address, could be covered by the data collected in the online survey.

Step 1.

An online survey is distributed through the relevant channels in order to collect forest owners' preferences in the study area. The survey is based on the questionnaires from the existing publications that applied the same methodological approach (Chreptun et al., 2023; Gosling et al., 2020). Some of the questions were expanded or included based on the existing studies on the factors influencing the decision-making of NIPFs. The survey is available in English, German, Italian, French, and Slovenian languages.

Step 0: Draw a baseline in the area of the Living Lab

- Assess actual forest composition based on the data from the Living Labs
- Evaluate ownership structure and forest holdings/enterprises size range

Step 1: Measure stakeholder perceptions and survey additional information

- Online survey for forest owners

Step 2: Determine optimal forest composition

- Mean performance scores for each forest type and the associated variation of each indicator for
    - Forest owner type (e.g., according to the ownership length and property size)
    - Living Lab
    - Country
    - Alpine space

  → Robust, multi-objective optimization for:
    - Each forest owner type
    - Living Lab
    - Country
    - Alpine Space

    Against:
    - All indicators
    - Market objectives
    - Non-market objectives
    - Management effort objectives
    - All possible combinations of objectives/indicators
    - Most important indicators
    - Single indicators
- Sensitivity analysis:
    - Uncertainty level
    - Weighing
- Assess the performance of the optimized forest composition

Step 3: Identify factors driving forest management decisions

Which of the optimized forest compositions are most similar to the current forest composition in the area of the Living Lab and/or respective forest holdings/enterprises? What forest management objectives could best describe actual forest management decisions of the forest owners?

- Compare optimal and current forest composition: Bray-Curtis measure of dissimilarity

Step 4: Validation of results

- Interviews with the participants of the survey to validate the conclusions drawn from the analysis

Box 1. Methodological outline.

The survey is structured as follows:

1. Assessment of performance of forest types against each indicator, i:

    a. Forest types can be assigned the same score.

    b. In order to avoid prompting comparison between different indicators, following principles of a weak comparability and incommensurability of values (Martinez-Alier et al., 1998), each indicator appears separately and in a random order. The general preference indicator is not randomized as it includes everything else not covered by the suggested indicators.

2. Owner's objective and subjective factors:

   This sub-section is intended to collect socio-demographical data about respondents and further information that could be later used for supplemental interpretation of forest management decisions like bequest and sentimental values (Gatto et al., 2019).

3. Property structural characteristics:

   In this sub-section, additional information about forest property that is believed to influence forest management decisions is collected (Gatto et al., 2019). Moreover, data collected in this sub-section could be used to address data scarcity issues, as described in Step 0.

4. Forest management factors:

   This sub-section is designed to collect further information about current forest management. It includes weighing different indicators to be later used in a sensitivity analysis (Gosling et al., 2020), as well as respondents' opinion on their forest's performance against all indicators, to further compare forest owners' preferences, perceptions about their forest, and the real performance.

The question groups were ordered in the following way to improve the objectivity of the answers and avoid respondents connecting the forest types to their own forests. The group where indicators appear for the second time was ordered last to avoid fatigue due to repetitive information.

Step 2.
Table 11 lists all the variables and indexes relevant to the description of this step.

Table 11. Outline of variables and indexes in multi-objective, robust optimization model.

Variable	Description	Index	Description
i	Indicator	f	Forest stand type
u	Uncertainty scenario	k	Individual respondent (forest owner)
$D_{i,u}$	Distance between the target and achieved performance level of a given forest composition for a given indicator, i	k_t	Forest owner type[13], where t is a type
a_f	Allocated share of each forest stand type, f	l	Living Lab
$p_{i,f}$	Performance score of each forest stand type, f, for each indicator, i; $\hat{p}$ is an estimated performance score	fr	France
$SEM_{i,f}$	Standard error of the mean	at	Austria
SD	Standard deviation	it	Italy
m_u	Uncertainty factor to determine deviation from the performance score	slo	Slovenia
$p_{i,f,u}$	Uncertainty adjusted performance score, where $p_{i,u}^*$ is the highest uncertainty adjusted performance score, and p_{i,u^*} is the lowest uncertainty adjusted performance score, given by the forest stand type	de	Germany
U_i	Uncertainty Set	alp	Alpine Space
F	Number of forest stand types	o	optimal
w_i	Weight derived from the indicator importance ranking	c	current
n	Sum of all "best" and "second best" rankings across all forest stand types		
r_f	Relative frequency of the rankings "best" and "second best" for a given forest stand type, f		
$P_{i,u}$	Forest property level performance		

[13] To be determined during the analysis

Based on the collected data, the mean performance scores of a given forest type f, and the associated variation of these scores ($SEM_{i,f}$), are calculated against every indicator, i, according to the preferences of different types of forest owners, k_t, Living Labs, l, countries (see Table 11), or Alpine space, alp, all together (Eq. (1)-(4)). The possibility to derive implicit management objectives on each of these levels depends on the data availability (i.e., survey response rate). Equations (1)-(4) are used for the estimation of the mean performance scores based on the responses of all forest owners (Eq. (1) and (3)); the variability reflects differences in perceptions of survey respondents (Eq. (2) and (4)); to estimate a performance score on a different level, a different index would be used instead of k (see Table 11, column "Index").

$$\hat{p}_{i,f} = \frac{1}{K}\sum_{k=1}^{K} p_{i,f,k} \quad for\ i = 1,2,3,\ldots,6,8,9 \tag{1}$$

$$SEM_{i,f} = \frac{SD_{i,f}}{\sqrt{K}} \quad for\ i = 1,2,3,\ldots,6,8,9 \tag{2}$$

Following Gosling et al. (2020), the general preferences $\hat{p}_{7,f}$ of forest owners (indicator 7 in Table 9) for a given forest type, f, were measured by the number of times that the forest type was ranked as the best or the second best option (Eq. (3)).

$$\hat{p}_{7,f} = (\#best + \#second\ best)_f \tag{3}$$

The standard error of this performance indicator ($SEM_{7,f}$) is computed by:

$$r_f = \frac{\hat{p}_{7,f}}{\sum_f^F \hat{p}_{7,f}} = \frac{p_{7,f}}{n}$$

$$SEM_{7,f} = n \times \sqrt{\frac{r_f \times (1 - r_f)}{n}} \tag{4}$$

The estimates are subsequently used as input in the robust, multi-objective optimization model. The optimization is formulated as a MIN-MAX (Chebyshev problem) (Romero, 2001), simulating a decision maker who wants to achieve the forest composition that improves the poorest performance across all management objectives. Each indicator has a target performance level, a highest possible performance score, $p_{i,u}^*$. The model allocates area shares to each forest stand type, a_f, to the optimal forest portfolio that minimizes the maximum (worst) shortfall from the target level across all indicators. Following a non-compensatory approach, the objective function cannot compensate for low performance in one indicator with high performance in another, seeking a compromise solution instead (Knoke et al., 2016).

Equations (5) – (8) formulate the optimization problem:

Minimize β (5)

Subject to:

$$\beta \geq D_{i,u} \quad \forall_i \in I \quad \forall_u \in U_i \tag{6}$$

$$\sum_f a_f = 1 \tag{7}$$

$$a_f \geq 0 \tag{8}$$

The objective function minimizes β, which denotes the worst underperformance of the forest composition portfolio across all indicators, i, and uncertainty scenarios, u. The underperformance is quantified with $D_{i,u}$, which is the distance between the target and the achieved performance level of a given forest composition for a given indicator. Uncertainty scenarios factor in potential variations in the capacity of each forest stand type to achieve every indicator. The inequation (6) summarizes individual constraints. To solve the allocation problem, shares to each forest stand type, a_f, are defined as variables. The optimization is carried out in Microsoft Excel using an open-source OpenSolver (version 2.9.3) (Mason, 2012). See D.1.3.2_Multi-criteria-approach_ROM.xlsx.

Input parameters for the model are the performance scores, $\hat{p}_{i,f}$, of each forest stand type and the associated standard error, $SEM_{i,f}$, as described in the beginning of this sub-section (Eq. (1)-(4)). To reflect the variability in the forest owners' opinion (i.e., uncertainty), we calculate optimistic (what could be expected in the best case) and pessimistic (what could be expected in the worst case) estimates, also referred to as uncertainty-adjusted values, $p_{i,f,u}$. For the optimistic estimate, the mean score is used. For the pessimistic estimate, we incorporate a deviation based on the $SEM_{i,f}$, uncertainty factor, m_u, and the direction of the indicator (as described in Table 9):

Optimistic estimate $p^+_{i,f} = \hat{p}_{i,f}$

Pessimistic estimate $p^-_{i,f} = \begin{cases} \hat{p}_{i,f} - m_u \times SEM_{i,f} & if\ more\ is\ better \\ \hat{p}_{i,f} + m_u \times SEM_{i,f} & if\ less\ is\ better \end{cases}$

for all indicators, $i = 1, 2, 3, \ldots, 9$ (9)

The factor m_u determines the size of deviations in the pessimistic estimate and thereby reflects the uncertainty level in the model, where $m_u = 0$ excludes uncertainty, $m_u = 1.5$ stands for a moderate uncertainty level, and $m = 3$ represents a high level of uncertainty (Knoke et al., 2016). We compute values with different uncertainty levels to perform sensitivity analysis.

The uncertainty-adjusted values, $p_{i,f,u}$, optimistic and pessimistic estimates, form the uncertainty scenarios, u. Each uncertainty scenario consists of a unique combination of optimistic and pessimistic estimates across the seven forest stand options, resulting in an uncertainty set, where F stands for the number of forest stand types:

$$U_i = 2^F \tag{10}$$

In our case, the optimization accounts for 576 uncertainty scenarios ($2^6 \times 9$ indicators). Based on uncertainty-adjusted values, the optimization model determines overall performance of a hypothetical forest property, $P_{i,u}$, comprised of various shares, a_f, of the six forest stand types:

$$P_{i,u} = \sum_f p_{i,f,u} \times a_f \tag{11}$$

Then, the distance $D_{i,u}$ between the target ($p^*_{i,u}$ or p_{i,u^*}) and achieved levels ($P_{i,u}$) is normalized between 0 and 100, where 100 means the best possible performance for a given indicator and uncertainty scenario:

$$D_{i,u} = \begin{cases} \frac{p^*_{i,u} - P_{i,u}}{\Delta_{i,u}} \times 100 & if\ more\ is\ better \\ \frac{P_{i,u} - p_{i,u^*}}{\Delta_{i,u}} \times 100 & if\ less\ is\ better \end{cases} \tag{12}$$

$$\Delta_{i,u} = p^*_{i,u} - p_{i,u^*} \tag{13}$$

where

$$p^*_{i,u} = \max_f\{p_{i,f,u}\} \rightarrow \text{for "more is better" indicators} \tag{14}$$

$$p_{i,u^*} = \min_f\{p_{i,f,u}\} \rightarrow \text{for "less is better" indicators} \tag{15}$$

Lastly, β denotes the maximum $D_{i,u}$ across all indicators, or in other words, the poorest underperformance that a forest owner would have to accept for any indicator in a worst-case scenario (Eq. (16)). $100 - \beta$ represents the guaranteed performance of a hypothetical forest property (the minimum performance attained for all indicators across all uncertainty scenarios, where 100% is the target level).

$$\beta = \max_{i,u}\{D_{i,u}\} \tag{16}$$

To derive the management objectives of the forest owners, the optimization problem is solved using various combinations of indicators, as detailed in Box 1 (see Step 3).

For the sensitivity analysis, we factor in weights w_i derived from the indicator importance ranking, additionally collected with the survey:

$$\text{Minimize } \beta,\ \beta = \max_{i,u}\{D_{i,u} \times w_i\} \ \text{ for indicators } i = 1, 2, 3, \dots, 9 \tag{17}$$

Step 3.

To assess which objectives and/or indicators are most compatible with forest owners' observed behavior, we compare the current forest property composition with the portfolios, optimized by different indicator bundles. Indicator bundles are listed in Box (Step 2). It is assumed that the indicator bundle generating a forest composition closest to the actual aggregated forest composition of our sample will be representative of the objectives driving forest owners in their decision-making. To assess the similarity, the Bray-Curtis measure of dissimilarity is used (Chreptun et al., 2023; Gosling et al., 2020; Knoke et al., 2016) (Eq. (19)). Values close to 0 indicate low dissimilarity, meaning that the forest composition optimized by a given bundle of performance indicators is the most similar to the actual forest composition.

$$BC_{o,c} = \frac{\sum_{f=1}^{F}|a_{f,o} - a_{f,c}|}{2} \tag{19}$$

Step 4.

Finally, interviews with the survey participants will be performed to validate the conclusions drawn from Step 3.

Example of an outcome and interpretation

Note that the following example is provided for purely demonstrative purposes as it is based on hypothetical data. Here, an example of an outcome for the Living Lab N is presented.

Step 0.

According to the data collected from the survey respondents, the aggregated forest composition in the area of the Living Lab N is as follows:

- Conifer, even-aged – 25%
- Conifer, uneven-aged – 12%
- Deciduous, even-aged – 10%
- Deciduous, uneven-aged – 19%
- Deciduous and conifer, uneven-aged – 28%
- Forests without intervention – 6%

80% of the forests in the area of the Living Lab N are owned by small-scale forest owners. Therefore, the current analysis is highly relevant.

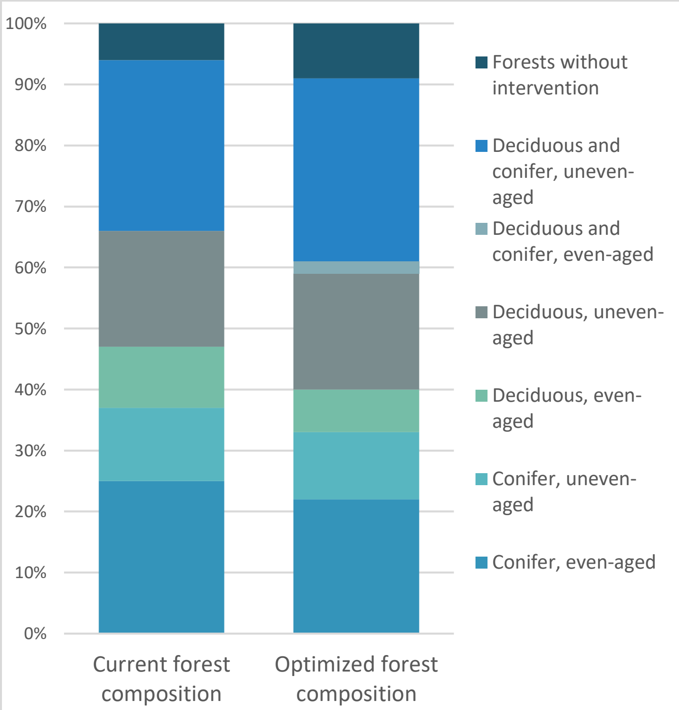


Figure 5. Comparison of the current forest composition in the Living Lab N and a hypothetical forest composition optimized by non-market and management effort objectives.

Step 1.

A total number of 30 small-scale forest owners completed the survey.

Step 2.

As a result of multiple iterations, an optimized forest composition was determined with the closest distribution of forest types – a hypothetical forest composition, optimized by non-market value and management effort indicator bundles (as in Table 9) (Figure 5). In this case, the Bray-Curtis measure of dissimilarity equals 0.057. Contrastingly, the Bray-Curtis measure of dissimilarity for the hypothetical forest composition optimized by market value indicator bundles is 0.75. Based on this result, it's possible to conclude that private small-scale forest owners in the area of Living Lab N are driven by the non-market value of their forests, as well as the effort required for their management.

In addition to this analysis, the results of the bio-physical assessment (i.e., the current performance of the forest regarding selected FES) and the performance of the optimized forest composition could be compared. This would allow for getting a direction toward potential solutions for better FES provision in the area of the Living Lab N.

Step 3.

Follow-up interviews with some of the survey participants, as well as the forest owners who did not participate in the survey, to validate the conclusions drawn from the optimization model.

These results indicate that private forest owners are the main target group for enhancing the provision of non-market FES in the forests of Living Lab N. However, they face management complexities and require additional incentives and support in that regard. Conversely, focusing solely on new profit-generation opportunities may not be the most effective strategy for addressing this stakeholder group.

Potentially, the analysis could be downscaled to the different types of forest owners based on various criteria (e.g., ownership length, property size, age, etc.). Identifying implicit objectives of different forest owners can provide us with a clearer understanding of where the potential hotspots of FES are (i.e., what forest owners should be targeted to ensure successful implementation of the Living Lab, what kind of incentives should be offered, and what kind of business models/markets should be developed).

Methodological limitations

The first limitation is related to the choice of the forest type. The choice of a generic forest stand type aims to simplify the survey, broaden its reach, and enable transnational applicability of the method, as well as facilitate the comparison of the results. However, potential ambiguity in the data may arise due to these simplifications, as the survey respondents' perceptions of the forest types may differ greatly. In fact, the outcomes might have been different if more specific forest types were chosen. Using broader definitions allows for reaching a larger number of respondents and capturing diverse opinions, thereby compensating for potential data ambiguity.

Secondly, the model does not account for the actual feasibility of achieving a certain forest composition, as well as political, legal, and environmental restrictions.

Thirdly, the model developed for the Forest EcoValue project is static, serving the project's current objectives but limiting insights into future developments.

Moreover, bio-physical indicators were not integrated into the model due to data scarcity issues. The outlined methodology that solely relies on the surveyed data will ensure transnational comparability. Nevertheless, the flexibility of the model allows for adding more indicators in case it is required in the Living Labs.

Finally, the survey is tailored to collect information from the private forest owners. However, if necessary, it can be adjusted to cover a wider range of stakeholders. When the representativeness quota is achieved, an examination of different stakeholders' perspectives as well as which group drives forest management decisions in the Living Labs could be conducted.

3. Market-based instruments (MBIs) for forest ecosystem services (FES)

Forests offer a wide range of benefits that support human well-being. They provide economic, social, and environmental values and play a vital role in maintaining ecosystem services. Although forests provide tangible products such as timber and fuelwood, which are considered private goods with their own markets, they also have a crucial role in offering ecosystem services. These services include air and water purification, carbon sequestration, and habitat provision, which are both public goods and positive externalities that are not accounted for in the market price for timber. The benefits derived from forests extend beyond individual owners, encompassing broader societal gains. However, the private interests of forest owners – since they can only profit from a small fraction of FES – usually do not align with the broader social benefits forest ecosystems generate. This discrepancy highlights the need for an intervention to internalize externalities and ensure a more efficient allocation and production of forest resources.

Forest EcoValue is set to introduce an innovative approach to FES to bring out new business opportunities for forest owners while protecting FES. Before getting into the details of this approach, it is important to first understand the fundamental premise that underpins the need for market-based instruments (MBIs) for FES. The following sections will present a rationale for market-based initiatives for FES. Additionally, there will be a brief overview of potential MBI applications. The tool that was developed by WG ECO for market potential will also be discussed, along with an approach for assessing market suitability.

Introduction

The provision of FES requires effective management. Mostly, policy theory agrees that this can be done through regulatory approaches or economic instruments.

Whitten et al. (2009) identify three categories to divide possible government interventions:

- **Facilitative measures**: designed to enhance the exchange of information and bolster ecosystem services markets. Their goal is to provide technical and scientific information that can be utilized to improve information asymmetries, but also to provide support to facilitate market creation, for example by helping to reduce transaction costs.
- **Coercive/regulatory measures**: decided and enforced by governments that impose prohibitions or obligations. They are, for example, laws regulating the access to and use of an ecosystem service.
- **Incentive measures**: aimed to change stakeholder behavior by offering incentives. Market-based instruments (MBIs) fall into this category. They are considered more efficient and flexible and encourage positive externalities. MBIs often are hybrids and can also include aspects of the first two categories: they can be further divided into *price-based* and *quantity-based* instruments.

Price-based instruments

These instruments create a *price signal* for ecosystem services or *modify existing market prices* to reflect the impact on ecosystem services. Some examples are performance bonds, taxes, subsidies auctions, tenders, grants, payments for ecosystem services (PES), and markets for ES (MES).

PBIs adjust costs and benefits associated with the delivery of ecosystem services in order to provide a signal on the value of their provision. This happens since ecosystem services are hardly traded in markets, due to a set of intrinsic limitations that differentiate them from the classical goods exchanged in markets. Consequently, allowing parties to act solely in their self-interest can lead to a reduction in the provision of ecosystem services, which is detrimental to society as a whole. Encouraging the applications of PES and/or MES can help to bridge this gap.

Brief presentations of two of these instruments are as follows: PES and markets.

Payment for ecosystem services (PES)

A PES scheme defines a system where individuals or entities (typically public entities) pay landowners to preserve or enhance specific ecological services provided by ecosystems such as forests.

The reason to activate a PES scheme can be linked to the nature of ecosystem services as public goods. Their provision is socially desirable, but consumers and citizens fail to recognize the positive impact of FES: thus, too few public goods are supplied. PES incentivizes the provision of FES and aims to change the behavioral attitude to ecosystem deterioration. In general, ecology-oriented PES schemes posit that payments can be made to:

1) maintain or enhance ecosystem services,
2) rescue ecosystem services at risk,
3) prevent a change in land use with potential negative (ecological) impacts.

Accordingly, in all PESs there is (Muradian, 2010):

1) a resource transfer,
2) involving different social actors,
3) aimed at aligning land use with (sustainable) natural resource management.

According to Wunder (2005), five conditions must coexist for the implementation of a PES:

1) a transaction is voluntary,
2) a traded ecosystem service is well-defined,
3) there is at least one buyer for the traded ecosystem service,
4) there is at least one provider for the traded ecosystem service,
5) a provision of the ecosystem service is secured by the provider.

PESs operate on the *user pays principle*, where the recipient or beneficiary of an environmental benefit or positive externality compensates for it, where the compensation is directed towards specific environmental services like water purification, biodiversity conservation, or carbon sequestration.

A PES can be administered according to alternative models of governance (Schomers & Matzdorf, 2013; Matzdorf, et al., 2013), such as (Whitten et al., 2005)[14]:

- *Public schemes or government-financed PES*: buyers are others (government, NGO, or an international agency) acting on behalf of ecosystem services users
- *Private schemes or user-financed PES*: buyers are the actual users of ecosystem services
- *Public-private schemes*: a combination of public and private schemes (hybrids)

Markets for FES

A market can be defined as a place where buyers and sellers come together to exchange goods and services. It provides a platform for people to engage in voluntary transactions where they can exercise their property rights. One of the important aspects of markets is efficiency, which is a measure of resource

[14] We will see later how similar governance models are also applied to green infrastructures (GIs) and nature-based solutions (NbSs).

allocation that must meet certain conditions to ensure optimal outcomes. According to Perman et al. (2011), eight key conditions are necessary for an efficient allocation within a market framework:

1. *Existence of markets for all goods and services*: ideally, markets should exist for all produced and consumed goods and services within an economy.
2. *Perfect competition*: all markets should operate under conditions of perfect competition, where no single entity has significant market power to influence prices.
   Perfect information: transactors within the market should possess perfect information, ensuring transparency and rational decision-making.
3. *Full assignment of private property rights*: private property rights must be fully assigned for all resources and commodities, allowing for clear ownership and control.
4. *Absence of externalities*: externalities should not exist because they can lead to market inefficiencies by distorting prices.
   All goods and services are private goods: distinguishing characteristics of goods, such as public goods, private goods, open access, and congestible resources, must be recognized and appropriately managed within the market.
   Well-behaved utility and production functions: the utility and production functions of goods and services should exhibit stability and predictability.
5. *Maximizing behavior of agents*: all agents within the market are assumed to be rational maximizers, seeking to optimize their utility or profit.

In most cases, it is uncommon for all conditions to be fulfilled. This is especially true in the case of ecosystem services, as they are public goods that exhibit externalities and uncertainty about the ownership of some of the services. Consequently, it is difficult to prevent individuals who do not pay for ecosystem services from enjoying their benefits, a problem commonly known as free riding.

Our goal is to determine which markets are feasible within the Living Labs areas to enhance the provision of FES. This may entail some active policy interventions.

In the case of forests, most of them are privately owned, but the property rights for the services they deliver can be undefined (e.g. carbon sequestration). We will address these issues in the next section.

In theory, PES can exist also outside markets, since a payment can take place simply as a transfer of resources from one subject to another based on motivations different from the recognition of a mutual benefit deriving from trade, as it happens when a fine is paid. In a market for FES (MES), the acknowledgment of a mutually beneficial transaction is required. Table 12 lists some distinctions between MES and PES, where the distinctive characteristics of markets are identified.

Table 12 Characteristics of MES and PES

	Payments for FES	**Markets for FES**
Objective	Incentivize the provision of FES through direct payments to landowners	Incentivize the provision of FES through *structured markets with financial transactions, several actors and government intervention.*
Mechanism	Direct payments to providers based on the delivery of measurable outcomes.	FES are like commodities and their *price is determined by supply and demand dynamics.* There are several market mechanisms available (e.g. “cap and trade” and “auctions”).

Scope	Small scale (typically regional scale). They may focus on particular ecosystem services or specific geographic areas	Various scale, ranging *from local to international markets*. A wide range of FES is covered.
Regulation	They often rely on voluntary agreements between buyers and sellers	They involve *more formal regulatory frameworks* to govern market transactions, ensure transparency, and prevent market failures
Participants	buyers (beneficiaries, usually governments) and sellers (providers).	Broader market where *multiple parties can engage in buying and selling ecosystem services* (e.g. intermediaries)

Quantity-based Instruments

Quantity-based instruments for ecosystem services manage environmental resources by setting specific quantitative limits or targets. They focus on controlling the actual quantity of a resource and directly regulating its use, extraction, or preservation. Examples include *cap and trade* schemes, permit auctions, and offset schemes.

Market design for FES

Designing a market for ecosystem services (MES) requires (1) gathering contextual information, and (2) identifying and addressing aspects that lead to market failures.

Gathering contextual information is valuable for understanding the potential of a market that does not yet exist (and suggesting possible examples to implement) or evaluating its adequacy if it already exists. A possible assessment tool will be presented in the next section. We will refer to the tools developed within WG ECO for gathering information from Living Labs.

The tools developed within WG ECO for gathering information from Living Labs will be referenced.

FES market assessment

Within the scope of the tasks of the ECO Working Group, an assessment of markets for forest ecosystem services is required. To follow up on this, a template has been developed to be administered to the Living Labs' coordinators in order to determine how likely a market for FES is to work in a specific site. This assessment is possible based on a composite set of information, being partially qualitative or narrative and partially numerical or quantitative that link either to the forest ecosystems present in the site or to several conditions that refer to the type and dimensions of a running or potential market. This information closely links to the work on business models presented later in the report.

Initially, the tool was developed based on a literature review that identified the sections and subsections to be included. Then, the work underwent review by project partners, and following an iterative exchange, it was decided to propose two versions of the template to facilitate completion by living lab coordinators:

- One version applies to existing markets: some services (such as timber production) are private goods already included in markets. In this case, information will be collected on the current characteristics of the exchange, including the type of market and the business models used.
- One version applies to potential markets: each Living Lab (LL) has chosen a series of FES to focus on, but not every FES necessarily already has a reference market in the Living Labs area. Therefore, a simplified version of the template (where the sections inconsistent with a situation of absence of markets have been removed or modified) has been prepared. This template collects contextual information to suggest the most suitable market mechanism for the area.

Market templates

The tables have been organized by *eight macro-sections* that include up to *24 entries* (for existing markets) to be filled in for each LL, as shown in Table 13 below, also providing a short commentary for each macro-section.

Table 13 Macro-sections used in the table for FES market assessment in FEV LLs.

Macrosection	Description
Context	General features of the region where the LL is located including basic ecological and geographical information
Forest Ecosystem Service (FES)	Information of the forest ecosystem service (FES) for which a market or PES scheme has been or will be set up in the LL including quantitative, qualitative, cost of provisioning, alternative scenarios with/without the service
Scale	Information on the scale of the market, the quantity of the FES provided, its continuity, time-scale.
Actors	Information on the main stakeholders involved in the direct market transaction/PES scheme. Including information on ownership, beneficiaries, providers and intermediaries (if any)
Market	Information on the dynamics and functioning of the existing or potential market for FES including the reason why the market has been set up and information on payments type, entity, financial sources, and mechanisms
Benefits	Information on the types of benefits derived from the society at large from the existence of ecosystem services traded including the non-economic ones such as social and ecological benefits
Governance & Regulation	Information on the legal and policy background and support activities put in place by authorities, public administrations, or other governance bodies concerning the market/PES scheme.
Monitoring	Information on how the effectiveness or efficiency (and proper functioning) of the market/PES scheme can be assessed for increasing the information available to beneficiaries on the "value for money" generated through the market/PES scheme.

The macro-sections have been chosen based on a synthesis of the principal aspects typically analyzed within any market structure. They aim at collecting some basic information that we deem is strictly necessary to provide a qualitative assessment of the *adequacy of a regional FES market to be initiated or consolidated in a specific and clearly defined site* – namely each Living Lab, as described in the WP1 – WG BIO Report (Matrix).

The tables that have been elaborated for direct use in the FEV LLs include a structured selection of entries where information can be collected aiming at describing the characteristics of actual or potential markets for FES within any specific LL.

All the information is collected under a double conditionality:

1. It refers to a single FES out of the list identified for each LL (see Matrix developed under WP 1 WG BIO);
2. It refers to a single LL.

For instance, to investigate the Italian Living Lab where three FES have been chosen (e.g., CO2 sequestration, biodiversity, recreational use), three separate tables/templates need to be completed. Each table corresponds to one of the three selected services (i.e., one for CO2 sequestration, one for biodiversity provision, and one for recreational use of the forests).
In table 14 below, the individual entries (subsections) to be filled in for each Living Lab and for each selected FES are provided, along with a brief explanatory description.

Table 14 List of entries included in the table for FES market/PES scheme assessment in the FEV LLs. Both versions

Entry	Potential Market	Existing Markets
Title	The title should describe the main characteristics of the potential market: particularly FES type, location, ecosystem involved	
Country	Report the country where the scheme is applied.	
Region	Report the region, district, municipality, park, etc. where the scheme is applied.	
Ecosystem	Describe the ecosystem to which the market refers. Be as descriptive as possible and include any relevant information not found in other sources (e.g. WG BIO matrix)	
FES provided	Identify forest ecosystem service of interest e.g. provisioning, regulating, cultural, supporting	
Cost of the service	Indicate the cost to be borne for delivering the FES if possible using a standardised indicator/metrics. The cost of the service can sometimes coincide with the forest. If possible enter a quantity/number, otherwise enter qualitative information. management cost.	
FES scarcity scenario	Indicate the likely consequences of a significant variation of the FES investigated in case of extreme scarcity of the service itself. If possible describe the range for variation.	
Time scale	Indicate information on the duration of the FES in time (at least: long term, short term). Not always relevant.	

Entry	Potential Market	Existing Markets
Space scale	Indicate information on spatial borders / geographical scope of the project (local, regional, national, international). Note: usually FES have local reach, except some. This information is relevant in case of congestion.	
Beneficiaries	Try to compile a list of organizations and individuals who may participate as buyers in the FES market.	Describe the type of organizations or subjects that join the market as beneficiaries (buyers). You can ideally also include a detailed list of organizations or people (possibly report on the number or scale of the demand side)
Providers	Try to compile a list of organizations and individuals who may participate as sellers in the FES market. Sellers are those who make possible the provision of FES. They might coincide with the forest owners, for example. Be as descriptive as possible.	Describe the type of organizations or subjects that join the market/PES scheme as providers (sellers). You can ideally also include a detailed list of organizations or people (possibly report on the number or scale of the supply side)
Intermediary	Who among the stakeholders could play this role?	Describe the role of the intermediary in the PES scheme (if any)
Aim of the market	Clarify the desired objective of the market: e.g. preserving biodiversity, making profits, increasing public participation in natural resource management, etc.	
Business model		Briefly describe the plan for the success of the market
Payment mechanism	Describe if there is already a direct or indirect payment to those providing FES: if yes, how do they work (e.g. contractual agreement), and which is the source that originates the payment?	Describe which is the medium through which the exchange takes place
Payment type		Describe how the payment is organized between the parties involved.
Source of payment		Clarify which is the source that originates the payment
Ecological benefits	List all the ecological benefits from FES (possibly DMBs)	
Social benefits	List all the benefits (impacts) from FES that contribute to societal variables and poverty reduction (or vice versa) (possibly DMBs)	

Entry	Potential Market	Existing Markets
Regulatory framework	We are in a situation of market absence, however, in some way, is the ecosystem service recognized and/or regulated? Are there, for example, policies or direct and indirect support services for the service? (e.g. a protected area does not imply the presence of a market but gives an idea of a possible framework within which to situate the BM and its governance; volunteering and local associations should also be considered)	Briefly discuss the regulatory context where the PES scheme is being applied
Policy		Describe the main policies adopted for market development
Support services		Describe the services implemented to facilitate the success of the PES scheme
Success indicators/methods	Has the FES ever been measured locally? If yes, how?	Describe which methods have been utilized to prove the success of the PES scheme

To assist LLs coordinators in filling out the table, further information can be found in the *Guidelines*. Additionally, the guidelines come with a list of good practices (GPs) that showcase a comprehensive collection of case studies focusing on FES markets and PES. The list aims to gather consistent and relevant examples from various contexts within the European Union. Initial examples added by the FLA team kickstarted the data entry process, but the list is open to further contribution. The case studies will not only highlight successful instances of FES markets and PES but also document good practices observed within these frameworks. The information gathered will serve a dual purpose: to showcase a selection of GP cases and to identify the key facilitating conditions that enable their successful application in different sites across the EU. This work will produce valuable insights into effective strategies for ecosystem service management and payment mechanisms to be shared and applied in diverse environmental contexts.

Effective MBIs design

The effectiveness of MBIs in incentivizing landholders to provide ecosystem services is heavily dependent on the specific application context and design. Despite the global interest in MBIs as a promising approach, their success is strongly influenced by these factors.

Specifically, among the numerous aspects to consider in market design, the following three points are used to assess the market effectiveness or feasibility:

1. **Gains from trade**
   Whitten et al. (2009) affirm that the benefits of MBIs stem from the gains achieved through exchange, a fundamental concept in microeconomic theory[15]. MBIs operate on this principle by creating incentives for stakeholders to internalize the externalities associated with ecosystem

[15] The concept is that exchanges make everyone better off is based on the idea of comparative advantage and specialization. According to this theory, when individuals or economic entities exchange goods or services, each party tends to benefit because they can obtain what they want or need at a lower cost than what they would have to incur to produce it themselves. This leads to a more efficient allocation of resources, where each entity specializes in producing what it is relatively more efficient at and acquires what it needs from others.

services. By assigning value to these services and facilitating their trade, MBIs promote efficiency. This approach harnesses the power of market forces to achieve environmental goals while also fostering economic prosperity. Of course, exchanges involve costs: the benefits arising from exchange are only realized if they exceed the costs and, above all, if this pattern is consistent over time, meaning if the incentive remains constant and rewarding compared to business as usual.

The benefits arising from trade are made possible by introducing the concept of *heterogeneity*. This topic has been well explained in Reeson et al. (2009): according to the authors, a certain degree of variability and differences among stakeholders in terms of resources, preferences, and costs to be incurred are essential to building a market. In case of homogeneity among factors, there would be no incentive to exchange goods and services. They identify three types of necessary heterogeneity: biophysical, management options, and landholder heterogeneity.

In brief, biophysical heterogeneity refers to the physical characteristics of the area, how resources are distributed in the territory, and the availability of that particular service within the considered perimeter; management heterogeneity refers to the ability to undertake different actions to deliver the same ecosystem service, with costs and benefits that vary for each of these actions. Finally, stakeholder heterogeneity (primarily forest owners/landholders) means the quantity and distribution of resources they own (e.g., available time, size of their business, human capital, available technology, personal preferences), from which different cost structures derive[16].

For this assessment purpose, the analysis of heterogeneity is based on information and inputs derived from the work of the WG BIO and forestry experts. As depicted in Figure 6 (Reeson et al. 2009), the source of information to assess the level of heterogeneity depends on technical information concerning the identification of FES production potential and the selection of possible forest management actions (e.g., tree cutting type and frequency) to produce a FES.

This analysis is preliminary to deciding to introduce an MBI or rather opt for other instruments (such as facilitative ones): the decision of individual parties to enter a market ultimately depends on the costs stakeholders will incur and the incentive they would derive from participating. This information, in turn, depends on the costs related to forest management techniques that can be implemented for the same FES. Once information on *cost heterogeneity* is obtained, it is possible to proceed with a comparison of the available options that each stakeholder can consider to decide whether to enter the market or not.

The tool that will be presented later to assess market feasibility assumes an evaluation of heterogeneity made in line with these principles.

[16] The case of water markets is an example that reflects this reasoning: in this quantity-based instrument situation (cap and trade), there are actors who need to purchase more rights due to water-intensive crops, while others are willing to sell their shares because they manage different crops. This type of heterogeneity relates to management options and the diversity of actors, while another example related to biophysical heterogeneity refers to the variety of ecosystem service (ES) availability in the reference area: areas with abundant water and less abundant areas will have different extraction and management costs, thus motivating the need for some exchanges.

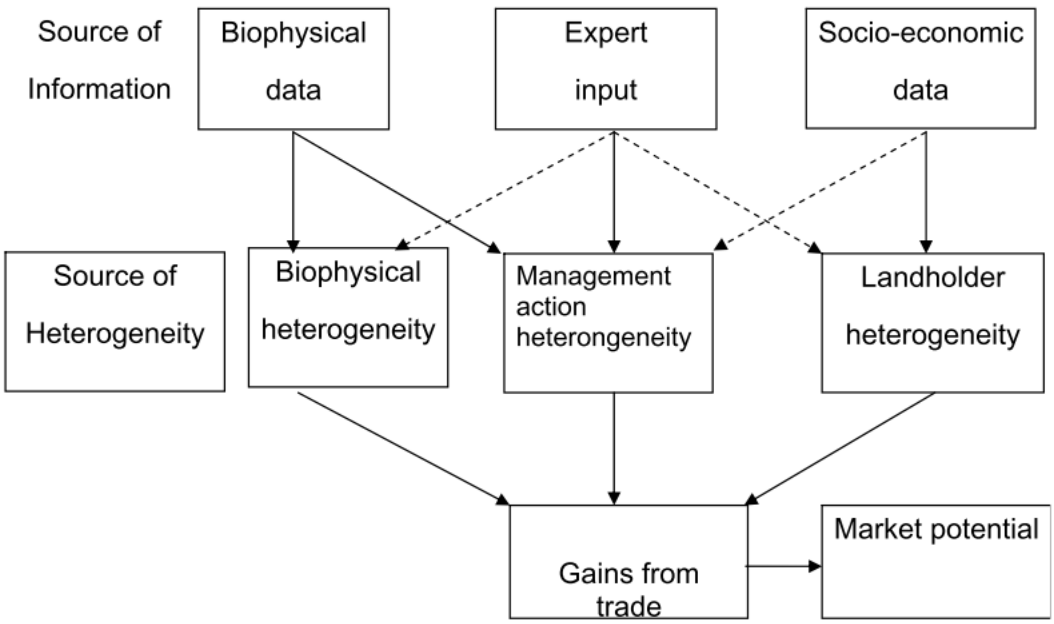


Figure 6 Conceptual approach to rapid assessment methodology for heterogeneity (Reeson et al., 2009).

2. **Market failures**

When designing market instruments, it is easy to encounter market failures due to the intrinsic characteristics of ecosystem services. Successfully identifying and overcoming these failures is a necessary step to define the most suitable instrument.

MBIs are intended to overcome market and government failures and other impediments to market formation, so as to allow gains from trade to emerge. The range of such failures in a specific context should be systematically identified as a basic input in the MBI design process (Whitten et al., 2013). In the literature, there are many examples of market failures that refer to a number of unmet market features (Whitten et al., 2004; 2009; Xiaolong et al., 2020; Fripp et al., 2014; Reeson et al., 2009). The four main ones for FES are listed below:

a) *Incomplete property rights*: they are the primary failure to address, as they are often present in ecosystem services, being public goods with positive externalities. The lack of a clear definition of ecosystem property rights can hinder the determination of benefits or costs resulting from land use impacts on ES, thus leading to free riding (Xialong et al., 2020). Specifically, issues related to property rights can be categorized into the following categories: *definable, measurable, excludable, transferable*.[17]

b) *Information failure or asymmetry*: occurs when one or both parties lack complete information about the ES. This means that buyers might not fully understand how their actions affect the environment or the true value of the ecosystem services they seek to purchase. This lack of awareness can lead to suboptimal decisions regarding ecosystem management and conservation. For example, consumers may not recognize the benefits of conserving specific habitats or biodiversity, leading them to undervalue these services and therefore be unwilling to pay fair prices. Additionally, sellers may not be forthcoming (either intentionally or unintentionally) about their practices or the environmental impacts of their activities, making it difficult for buyers to make informed choices. Addressing this information gap requires strategies to promote *transparency*, ensure *access to accurate information*, and

[17] For more information see the above-mentioned literature

enhance *awareness among market participants* about the benefits and environmental impacts of ecosystem services.

c) *Market structure issues*: challenges of a thin market, where there is insufficient participation. They require evaluating the necessary market size to ensure sufficient participation and minimize transaction costs while benefiting participants. Market power can also impair the proper functioning of trade: while creating a perfectly competitive market may be unrealistic, it is necessary to regulate cartels and monopolies.

d) *Constraints to market participation*: costs related to entering the market often create barriers. Facilitating mechanisms can reduce them. Low transaction costs encompass all the expenses associated with buying and selling in a market (e.g. time to agree on the nature, extent, and timing of the payments or in-kind transfers, creating contracts, and monitoring the outcomes of the agreement for all parties): they are crucial for the success of a functioning PES scheme.

3. **Supporting mechanisms**: MBI design must incorporate supporting mechanisms, such as regulatory change, or communication and engagement programs. Opportunities to nest MBIs within existing institutional and organizational architectures in order to reduce transaction costs should also be identified where appropriate. Supporting mechanisms are often policy-driven and may require an involvement of policy makers for implementation.

Assessment of the feasibility and potential of MBIs

MBIs have significant potential, particularly in terms of cost-effectiveness, but they cannot be applied to all situations. Hence, the contextual information that we aim to collect in the template allows for evaluation of two complementary aspects:

- **Biophysical Context**: it encompasses a comprehensive understanding of the geographical locations and mechanisms through which the FES is generated. It involves analyzing spatial constraints, such as ecological boundaries and resource availability, and evaluating the effectiveness of management strategies implemented by diverse stakeholders in fostering the production of the service.

- **Community and Business context**: assessing the potential consequences of introducing new policies and MBIs on the local community and business environment is essential. Understanding the possible impact of these interventions on social cohesion, economic activities, employment patterns, and the overall well-being of community members is crucial. Additionally, it is important to consider how businesses might adjust to or be impacted by the implementation of new regulatory frameworks or market mechanisms, including potential changes in market dynamics, investment decisions, and competitiveness within the affected sectors.

The situation leads to considering two different conditions: on one hand, the case of existing and operational markets, and on the other hand, the case of FES for which a market needs to be created from scratch.

The method for analyzing the responses collected to the template is based on the general theory of markets and its application to FES, which by their nature have peculiar characteristics. The selection of template entries is useful to provide a context within which to evaluate the feasibility or current efficiency of a market for a certain FES and gives us the necessary information for the business models section as well.

Given the aforementioned conditions, the purpose of this analysis is twofold: for situations where a market exists, feedback will be provided on possible improvements to enhance efficiency and overcome any market failures that may exist. The aim is not to propose new markets, but rather to improve the existing conditions. On the other hand, for potential markets, it will be possible to provide a general indication of the possible form that a market for FES could take, as will be seen in the next section.

Market assessment for MBIs

For this type of work, the methodology followed consisted of analysing existing literature related to the design and evaluation of MBIs to select the main categories to consider in a real-world scenario as the Living Labs. These findings were incorporated in Table 15, listing the indicators to assess the market's adherence to an ideal archetype. Once data from the Living Labs are obtained, they will be compared with these indicators. Further information that might be needed will be requested to the Living Labs' coordinators at a later stage.

Table 15. Indicators to assess the market's adherence to an ideal archetype

Indicator	Description	How to assess	Archetype/model answer
Issue or threat	Is there a specific problem, such as loss in biodiversity, or a service, like carbon sequestration, that is recognized by at least one set of stakeholders, who are willing to pay to rectify/address the situation?	*There must be a clear cause and effect*	buyers must know that the FES they are willing to pay for will provide the desired benefit
Rivalry and Excludabilty	What kind of FES is it? Private good, public good, club…	*Rival/Non rival* *Excludable/non excludable*	Private good are more suitable for establishing MBIs, but it is possible to address also other types of good.
Number of FES	Is the ecosystem service provided individually or in bundles?	*Single* *Bundle*	It is often difficult — and possibly misleading — to isolate and pay for just one ecosystem service without simultaneously considering other services. The choice should consider the biophysical and management option heterogeneity at LL levels.
Clearly defined	Nature and extent of the property right is unambiguous: the nature and extent of property rights need to be defined by law and confirmed through registration	*Yes* *No*	Yes Nature and extent of property rights are clear and there is a registration system.
Verifiable	Use of the property right can be measured at reasonable cost.	*Yes* *No*	Yes There is a correlation between

			property right and ES. Transactions cost are low.
Enforceable	Ownership of the property right can be transferred to another party at reasonable cost.	*Yes* *No*	Yes Enforcement of property rights is mandatory. Compulsory realization requires supporting measures, such as fines, security deposits, etc
Valuable	There are parties who are willing to purchase the property right.	*Yes* *No*	Yes Property rights related to ecosystem services are valuable
Transferable	Ownership of the property right can be transferred to another party at reasonable cost	*Yes* *No*	Yes Transaction feasibility : There is a platform for review and supervision to reduce transaction costs.
Low scientific uncertainty	Use of the property right has a clear relationship with ecosystem services	*Law* *Moderate* *High*	High Use of the property right has a clear relationship with ecosystem services
Low sovereign risks	Future government decisions are unlikely to significantly reduce the property right's value.	*Low* *Moderate* *High*	Low Future government decisions are unlikely to significantly reduce the property right's value.
Typology and number of sellers	Who owns the ecosystem service? Who is legally entitled to sell the ecosystem service? forest owners local governments firms	*Low variety* *Moderate variety* *High variety*	Moderate to high variety. N.B. Sometimes high variety means higher transaction costs
Typology and number of buyers	Who is going to buy the ecosystem service? Is the buyer known to the seller? Citiziens governments NGO firms	*Low variety* *Moderate variety* *High variety*	moderate to high variety. N.B. Sometimes high variety means higher transaction costs
Are there any intermediaries?		*yes* *No*	
Width	What scale is large enough to avoid thin markets, but small enough to ensure geographically relevant benefits for purchasers?	*small portion of the LL* *medium portion of the LL* *all/big portion of the LL*	Largest relevant geographic scale to avoid thin markets. It depends on the width of the LL area.

-	Would action have been taken without the intervention?	*Yes* *No/unlikely*	No/unlikely. We have a baseline scenario thanks to which we can evaluate and compare the MBI implementation.
Accessibility to the market	i.e. codyfing property rights, seeking out buyers or sellers, negotiating a sale, measuring the quality and quantity of goods, specifications about the transfer of property rights	*Low* *Moderate* *High*	Low
Cost structure	Are fixed and variable costs mentioned? What are the characteristics of the forest (physical features, tree species, accessibility, threats, risks, and management objectives) that might influence the cost strucure (cfr. excel FM costs)?	*See the FEV_forest management cost document (in progress)*	Management costs are known.
Presence of market friction instruments	Are there any market friction instruments? Market friction instruments are designed to remove or reduce impediments to existing or potential markets for ecosystem services and thus improve the flow of signals and incentives there in;	*Yes* *No*	It's feasible to adopt market friction instruments to facilitate the flow of information.

Market assessment for potential MBIs

The template on potential markets for FES, as mentioned earlier, required some modifications to the original template to adapt responses to cases that do not yet exist in reality. The information requested will be equally useful for gaining a greater understanding of the context, and Table 15 will also be used for these cases. However, to provide a general indication of the best form of MBI (primarily price-based or quantity-based), a selection of discriminating categories for choosing the opportunity to create a market will be used: heterogeneity and definition of property rights, as previously indicated.

The choice of the best form of market instruments is the result of a process of identifying and overcoming market failures that may hinder the conditions for market creation. The criteria chosen at this stage are *heterogeneity* to assess whether MBIs are indeed the most suitable instruments, and subsequently, the existence and type of *property rights*, which are the criteria for implementing a market system. Without defined rights, as already mentioned, it is not possible to establish a payment and exchange system accepted by all the stakeholders involved. An additional section on excludability may be added according to the results from the analysis of the template.

Graphically, the selected tool draws from the works of Whitten et al. (2004, 2009, 2013), which provide a decision tree to assess the best MBI (Fig. 7).

In evaluating the best choice, certain rationales can justify the adoption of a price-based or quantity-based instrument, as indicated in Table 16, which encompasses the aforementioned aspects regarding the socio-economic context of the reference area. In broad terms, *quantity-based instruments* are preferred when there is a specific quantity target, low additional costs for providing ecosystem services, the presence of damage thresholds, environmental outcomes are seen more as a duty than a reward, or when there are significant time lags in achieving the desired results. On the other hand, *price-based instruments* are preferred when there is a fixed budget, additional actions come with high costs, payment is deemed acceptable, and outcomes can be achieved within the payment period.

Table 16. Rationale for preferring price or quantity-based instruments (Whitten et al., 2009)

PRICE-BASED	QUANTITY-BASED
Fixed budget	Physical targets
High cost of extra NRM	Low costs of extra NRM provision
Small benefits from extra NRM provision	Large benefits of extra NRM
The community should pay for NRM	The community has the right to the desired outcome
NRM outcomes quick to change	Long time to change NRM outcomes
Cost-sharing to achieve targets	Presence of thresholds with high NRM damage
small institutional changes (contractual powers to underpin the supply of ecosystem goods and services)	Significant institutional change
Long-term outcomes depend on the effectively cost-share investment in the long-term process	Longer-term outcomes achievable in short-term management goals
	Protection of existing outcomes

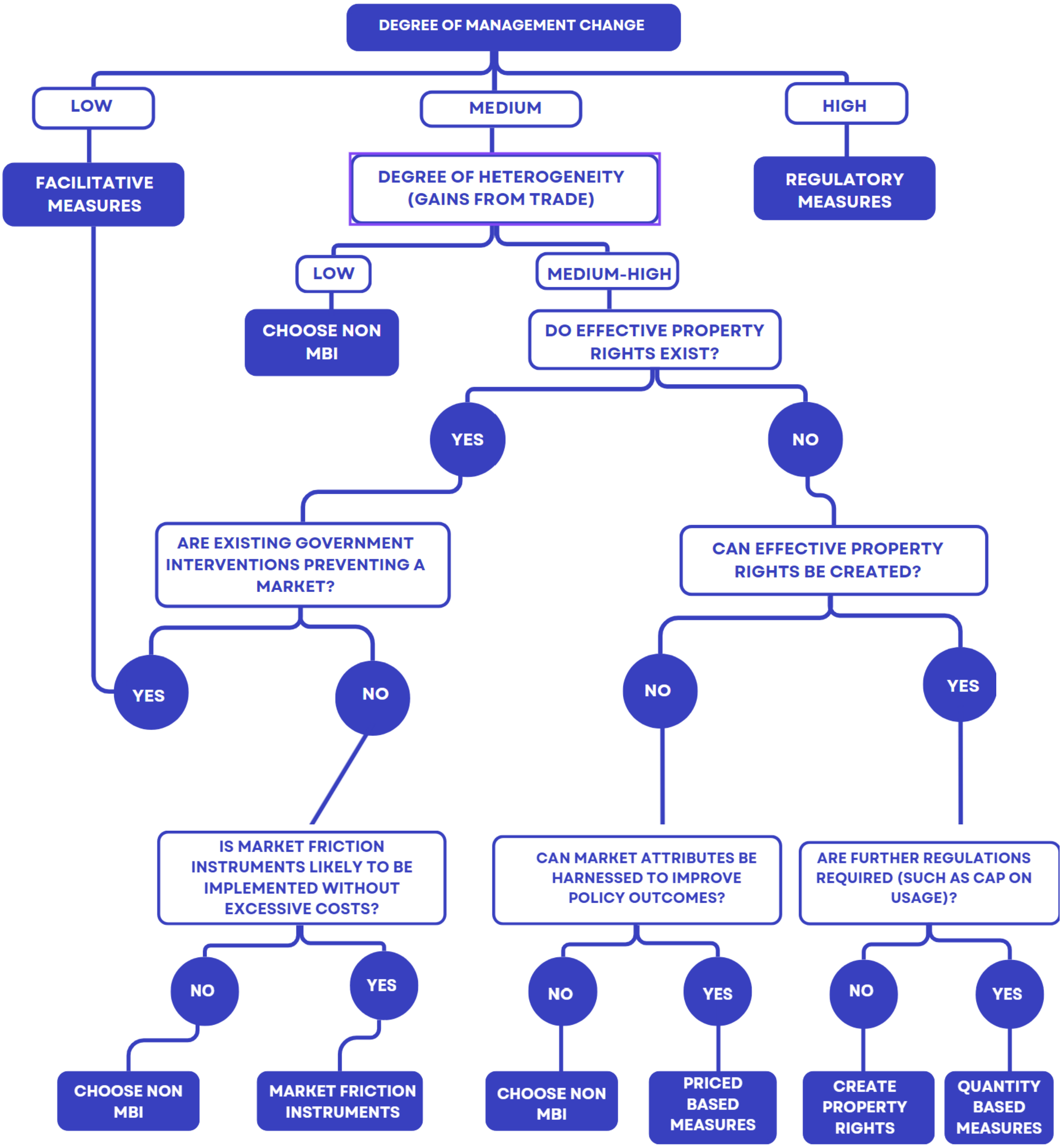


Figure 7. Decision tree for selecting appropriate MBIs

4. Business models for FES

Introduction

Forest ecosystems provide a set of services that directly or indirectly benefit the society. However, many of those services cannot be satisfactorily supplied in the absence of any form of supply management. Other services can require a specific type of forest management to survive over time, or even exist. Additionally, some of those services show a distinctive set of features that make them complex to recognize, quantify, and thus sell to, or appropriate by any subject.

Against this background, business models (BMs) offer an opportunity to manage at least some FES for revenue and create a good motivation for private or public organizations, communities or other groups and entities to commit to the supply of ecosystem services through appropriate forest management techniques.

The concept and aim of business models

The Business Model (BM) concept aims to explain how an organization creates, delivers, and captures value for itself, its clients, and the society (Osterwalder, 2005).

A BM attempts to explain those reasons of business success that cannot be directly related to a single dimension responsible for value creation, rather linking to a more complex and nuanced interaction of factors. Thus, a BM has been interpreted as a unit of analysis that captures various, different but interdependent sources of value (including efficiency, complementarities, lock-in[18], novelty, etc.) and focuses on how transactions, structures and governance are designed within an organization (Amir & Zott, 2012).

All BMs eventually aim at explaining – and possibly replicating – the way in which economic value is created and economic activity conducted by business organizations. A company creates value for its customers by satisfying a desire, solving a problem and achieving tasks that meet a need or align with a preference of individuals, groups, or other organizations. The benefits deriving from BMs are wide and multiple, so that customers, shareholders, suppliers, and partners, as well as the environment and society, all may benefit from business model innovation (Baldassarre, Calabretta, Bocken & Jaskiewicz, 2017).

Key to understand the success of a given BM is often its capacity to bring some innovation in current business practice. At least for a while, a BM can differentiate the company that adopts it from its actual or potential competitors, for instance creating a competitive advantage or allowing it to access a niche market of some sort. This explains well why much emphasis is placed on BM when it comes to launching new ventures and business ideas, and particularly in the framework of the so-called "startup ecosystems". Research has shown how the choice of some types of BMs seems to increase the rate of survival of startups by delivering a better and long lasting economic performance (Weking et al. 2019).

A BM primarily refers to the **firm's supply side**, i.e. to its internal organization, governance, processes and operations, and – at least in principle – it does not affect directly the product or service conveyed to customers. A BM is more about the way in which a business works than about what it sells or delivers. However, a BM depends on the context where the company operates, and it can be shaped so to address business decisions related to external factors, and the environmental conditions that make up the business environment, markets, and value creation strategy.

[18] A vendor, proprietary, or customer lock-in makes a customer dependent on a vendor for products, unable to use another vendor without substantial switching costs.

In recent years, the BM theory – i.e. a systematic use of BMs as a tool to achieve multiple benefits, especially value creation and delivery for firms and other economic organizations – has been tested in different sectors, including in enterprises related to the green economy paradigm. This is the case of the modified and adapted BM for companies working in the field of nature-based Solutions, green infrastructure (Ferranti & Jaluzot, 2020), and ecosystem services (Hansson & Karlsson, 2022; Feger & Mermet, 2022; Bishop et al., 2010), including forest ones (Kajanus et al. 2019).

Features and problems with marketing FES

The creation of markets for ecosystem services – including those of forests (FES) – requires addressing items (i.e. the services) that can suffer from invisibility, problems in quantification and regular provision, non-excludability and free riding.

Under the point of view of visibility of FES, *regulating and maintenance services* suffer from invisibility to or major delays in human perception, so that they are often recognizable only over the long run. *Provisioning and cultural services* on the other hand are directly observable and often deliver easily detectable outcomes even in the short run (e.g. in agricultural production, forestry and fishing) (Dasgupta, 2021).

Under the point of view of their excludability in consumption[19], some FES can be problematic and give rise to free-riding behaviour hindering their trade and marketing. As a result, FESs can be qualified as a special type of *public goods* (PGs)[20], although not all of them fall strictly into this category (Table 17): according to their degree of excludability and rivalry, FESs can be further classified as pure public goods, global commons, club goods or even private goods (table 18).

Table 17. Examples of FES categories and provision of public goods

FES category	Excludability	Perception
Air purification	Difficult excludability	Delay (medium to long run)
CO2 sequestration	Requires sound scientific background to perform calculation	Indirect
Water purification and regulation	Partially excludable	Technical controls
Biodiversity conservation	Non-excludability	Expert perception, need for indicators
Recreation and cultural values	Easily excludable	May need marketing support
…		

Table 18. Characterization of FEV according to their rivalry and excludability features

CICES No.	Ecosystem service	Global Commons	Public Good	Club Good	Private Good
CICES 1.1.1.2	Provision of timber wood biomass				
CICES 1.1.5.3	Provision of fuel wood biomass				
CICES 2.2.6.1	CO2 storage and seqestration				

[19] Excludability is defined as the degree to which a good, service or resource can be limited to only paying customers, or conversely, the degree to which a supplier, producer or other managing body (e.g. a government) can prevent "free" consumption of a good.
[20] Public goods are defined by two main characteristics: non-excludability and non-rivalry. Non-excludability means that individuals cannot be excluded from benefiting from the good once it is provided, and non-rivalry means that one individual's consumption of the good does not reduce its availability to others.

CICES 2.2.1.2	Regulation of avalanche and mud slides				
CICES 2.2.2.3	Natural habitats in forests				
CICES 3.1.1.2	Recreational effects				
CICES 1.1.5.1	Provision of wild mushrooms, chestnuts, blueberries				
CICES 1.1.1.2	Provision of resin				
CICES 3.1.1.1, CICES 3.1.1.2, CICES 3.1.2.3, CICES 3.2.1.1, CICES 3.2.2.1, CICES 3.2.2.2	Ecotourism, outdoor sports, artistic and spiritual inspiration, therapeutic…				
CICES 3.1.2.4	Beauty of nature, aesthetic value				
CICES 3.1.2.1, CICES 3.1.2.2	Educational and research value of blackpine forest and resin production				
CICES 1.2.1.1	Seeds and fruits for reproductive materials				
CICES 2.2.2.3	Provision of habitats for wild plants and animals				
CICES 2.2.5.1	Maintenance of high quality fresh waters provided by plants and animal species				
CICES 2.2.1.1	Soil loss prevention and control				
CICES 2.2.1.2; CICES 2.2.1.3	Protection against natural hazards				

FES and their benefits as public goods?

It is known that one major problem with PGs is to make the beneficiaries (or anybody else) pay for their provision, and transfer the payments to the provider so to incentivise the continuation of the delivery of the PGs themselves. This difficulty can result in under provision of PGs in comparison to the *efficiency case*. Basically, the demand for PGs is either underestimated due to insufficient knowledge on the benefits PGs bring about, or the provider cannot cover the cost of an efficient provision, so it decides to produce less and leave a part of the demand unmet – which is socially undesirable.

Mostly, private markets fail to produce these goods efficiently when individuals can benefit from the provision of a PG without contributing to its production (these individuals are called *free riders*), that typically leads to underinvestment in PGs by the private sector.

The typical solution adopted for ensuring that PGs are (at least partially) supplied is to use public policy to this end, by transferring the responsibility for their provision to governmental institutions. Often, notwithstanding the direct involvement of the public sector in supplying PGs, the public provision is insufficient to meet the societal demand for PGs.

Alternative solutions are thus needed to address the problem of inefficient provision of PGs, and incentivise the private provision of PGs (*i.e.* having the private sector as a major supplier of PGs).

Such a provision already happens in some industries (e.g. pharmaceutical companies developing vaccines, Open Source Software developers, donor funded research, shared mobility services, etc.), but is still problematic in the case of some special types of PGs – including several ESs.

However, upon close observation, it is evident that each case of private provision of public goods found in our societies is based on a specific BM.

Role of BMs in supporting the provision of PGs

Research and practice have shown that BMs can play a crucial role in setting up payment schemes for PGs by leveraging market mechanisms and innovative approaches to encourage investment in the provision and maintenance of these goods. Different BMs can apply to public, mixed and private provision of PGs. Their main aim is about making the provision financially sustainable and sufficiently attractive for potential suppliers to enter such a trade. Though, also the public provision of PGs can receive substantive gains in cost-effectiveness and other desirable improvements from the introduction of a suitable, typically innovative BM – aligned to the above-mentioned interpretation of BMs (*e.g.* as in Amir & Zott, 2012).

Actually, there are several possible approaches that BMs offer private entities willing to provide PGs – a short selection of which is reported in Table 19.

Table 19. Selection of BMs used to support the provision of PGs by private sector organizations, with examples related to FES provision.

Business Models Archetypes for the provision of non-excludable public goods	Description	Examples related to FES
Donation-based / Crowdfunding	Outsourcing financial support for a project from general public (individuals, business, philantropic organizations), typically via the internet.	Conservation activities, non-profit organization that rely on crowdfunding for forest management
Subscription-based / Membership	Users pay a private organization a recurring fee to access goods or services offered by the organization itself that have public good characteristics. Revenue from subscriptions (fees) covers/participate to cover the costs of production and maintenance of the PGs	Access fee to forests amenities and recreational services, with daily, monthly or yearly passes
Freemium	Private organizations offer a basic version of their product or service for free, while charging a premium (price) for enhanced features or additional services, so to attract a wide user base by providing a public	Carbon footprint calculators (free) with personalized carbon offsetting plans (premium feature)

	good for free while generating revenue from users willing to pay for premium offerings.	
Advertising-supported	Private organizations offer public goods for free or at a reduced cost to users by monetizing advertising or sponsorships by a third party.	Advertisement on forest access apps, online platforms or on-site
Social enterprise	A company prioritizing social or environmental objectives alongside financial goals can use alternative BMs to generate revenue while providing PGs.	Sustaining Forest Ecosystem Services Through Social Enterprises: Motivations and Challenges from a Case Study in Scotland - https://www.researchgate.net/publication/351740774_Sustaining_Forest_Ecosystem_Services_Through_Social_Enterprises_Motivations_and_Challenges_from_a_Case_Study_in_Scotland
Public-private partnership	Forms of collaboration between public and private sector organizations to finance, develop, and manage projects aimed at providing public goods by sharing some risks and rewards.	the LIFE programm: https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/programme-environment-and-climate-action-life_en
		Andean Biotrade Program - https://www.thegef.org/sites/default/files/documents/promoting_finance_instruments_for_biodiversity_conservation_though_biotrade_in_the_andean_region.pdf%5B%7Bc.pdf
Impact investing	Provision of capital to private organizations that aim to generate positive social or environmental impact alongside financial returns or profit.	https://thegiin.org/assets/GIIN_Scaling%20Impact%20Investment%20in%20Forestry_webfile.pdf
Pay What You Want	A pricing mechanism where customers are allowed to choose how much, if anything, to pay for a given service or commodity	Individuals, local governments, communities and businesses benefiting from improved ecosystem quality from forests can contribute funds based on the value they perceive from these services.
Revenue sharing / partnerships	A symbiotic agreement between individuals, groups, or companies to share resulting revenues. Profit are redistributed among stakeholders.	Local communities can benefit from the provision of ecosystem services
Experience selling	Offer customers emotional experiences instead of transactions, building a lasting company-customer relationship through personalized interactions.	Eco-tourism, workshops, educational trips, sports
Trash to cash	Based on the concept of circular economy, used products or production scratch are collected to be transformed (upcycled) in new products	Recycling/Upcycling timber production scratches

Based on the existing practice in the use of BMs for easing and supporting the supply of PGs from both public and private organizations, we assume that they can help to generate revenue from FES. By adopting mechanisms such as pricing, activation of revenue streams, and cost-sharing arrangements applied to FES, BMs may be able to cover the costs of providing PGs, such as most FES are, and generate returns for investors.

The inner complexity of the way in which businesses operate has brought scholars to offer a long and variable list of components that interact with each other to deliver value to customers and the society at large, which are often included within specific frameworks used for analyzing and designing business solutions for successful market implementation.

Here, the focus is on the categories used to describe cases involving sustainable, green, circular, and even more specific arrangements[21]. Particularly, based on the classic reference of Österwalder and Pigneur's Business Model Canvas (2010), the discussion will focus on two recent evolutions of the classical BM theory, referring respectively to nature-based solutions (NbS) and Green Infrastructure (GI). It is also assumed that BMs can generate innovation and increase efficiency in business processes, aligned with the Business Model Innovation (BMI) theory, as presented in Ramdani et al. (2019).

In the paragraphs that follow, the case with business models for Nature-based Solutions and Green Infrastructures is presented and discussed briefly.

Business models for nature-based Solutions (NbS) and green infrastructure (GI)

Nature-based solutions (NbS) are all types of arrangements (sometimes with some infrastructural trait) inspired and supported by nature. NbS need to be competitive and provide multiple benefits to people and territories (cities, landscapes, seascapes): constitutive characteristics of NbS include: cost-effectiveness; simultaneous provision of environmental, social and economic benefits; contribution to building local resilience; resource-efficiency; system-orientation (UNEA-5 Resolution, 2022; EEA, 2021).

The case of financing NbS has been better investigated than the general one with ESs – likely since NbS are to some extent more directly dependent on human action and require active management and maintenance.

From the point of view of costs related to the setup, management, operation and maintenance of NbS, research has proposed to consider three phases that need funding (Toxopeus & Friedemann, 2017):

4. *Planning* (often financed through public funding, against the recognition that NbS provide PGs and social benefits),
5. *Capital investment* (capital costs associated with implementation, usually incurred over a short period of time), and
6. *Ongoing operational costs,* including maintenance (ideally to be financed through revenue generation).

If capital investment has been sufficiently studied, not enough is known concerning the life of NbSs in the long run and solutions are needed for securing a return on investment (McQuaid & Horizon Nua, link)[22].

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[21] Particularly interesting the research conducted over several years by Nancy Bocken: for a list of publication, visit her profile at Maastricht University here.

[22] Clearly, all the discussion presented so far refers to the category of sustainable business models. A common basis for all business models proposed as sustainable ones is their ability to deliver at least not harmful consequences on the environment and, or the society. In a wider sense, a SBM could be considered aligned with the concept of sustainable finance as related to the simultaneous delivery or maximization of economic, ecological and social value streams (Schoenmaker & Schamrade, 2019).

Specific BMs should therefore also address ongoing operational costs and especially set up a sufficiently attractive remuneration to private investors.

Since BMs tend to address the supply side and the internal organization of companies and ventures, they need to design and propose governance arrangements for NbSs. Research has already identified at least five alternative options (governance model types) suitable to manage NbS, which may also be considered against the goal of provisioning FES:

1. *Public/State-based forms of NbS governance:* Nbs or greening initiatives are traditionally funded, planned and managed by local public administrations. Political discontinuity in public administrations may, however, undermine the maintenance of the project on the long term.
2. *New public management*: PPPs and externalisation of services of public interest. Opportunities and costs of NBS governance are increasingly being shared between the private sector and local administration: NB projects can be supported by governments through funds and subsidies and managed by private businesses, triggering a win-win situation where long-term societal interests converge with short-term business goals and enabling continuous economic growth while avoiding irreversible changes to the global ecosystem.
3. *Collaborative forms of governance*, where NbS are subject to multi-stakeholder governance models where policy makers cooperate with citizens, businesses and civil society. For instance, short-term subcontracting to non-profit or private actors (e.g., for management of urban green spaces) is a useful system of citizen inclusion NbS.
4. *Bottom-up forms of governance*: grassroots efforts in building greening projects (i.e. community gardens), equitable green spaces beyond market logics.
5. *Industry and private-sector driven NBS governance*, for instance, in the construction of green roofs and facades, which are NB solutions predominantly implemented by the private sector.

Those governance models examples (Sekulova, F., Anguelovski, I.) can be considered as one of the features to identify for alternative BMs.

In order to allow the design and assessment of suitable BMs for managing NbS, a procedure has been proposed which includes the dimensions recalled in Table 20.

Table 20: Main categories for NbS business model canvas

Macro-category	***Sub-categories***	**Description**
Value proposition What is being offered in the market? Who is the customer?	*Environmental VP*	
	Economic VP	
	Social VP	
	Trade-offs	
Value creation and delivery What resources are needed? What network? What is the strategy?	*Key activities*	
	Key resources	
	Key Partners	
	Key Beneficiaries	
	Cost Structure	
	Cost Reduction	

Value capture What revenues, for whom?	*Capturing Value*	
Financing upfront costs What costs are being made (or prevented)? Which is the financial structure?	*Capital Expenditure Costs*	
	Sources of Capital Investment	
Enabling conditions and risks? What conditions enable this business model to be effective? What risks are taken?		

Another valuable experience with special types of BMs was developed for green infrastructures in the framework of the Alpine Space Programme "*Linking Urban and Inner-Alpine Green Infrastructure*" (LUIGI) project.

Green infrastructure (GI) is a term partially overlapping NbS that refers to a system of interconnected ecosystems, ecological–technological hybrids, and built infrastructures that provide contextual social, environmental, and technological functions and benefits. It encompasses a network of multi-functional green and blue spaces, both urban and rural, capable of delivering a wide range of environmental, economic, health, and well-being benefits for nature, climate, local communities, and prosperity.

To develop tools to capture and monetize the benefits from GIs, fostering economic activities that acknowledge the importance and need for ESSs and create economic, social, and ecological value from them, a tentative GI-based business model canvas has been developed. Based on the original BM canvas (Osterwalder & Pigneur, 2010) and on the NbS BM canvas, it includes the categories summarized in Table 21 and shown as a canvas in Figure 8.

Table 21. Categories of GI-based Business Model canvas and their descriptions (LUIGI project)

Category	Description	Question	Examples
Value Proposition	How the value is generated, what is the trajectory that the value covers	What are the ecosystem services that create value? How can I valorize the ecosystem benefits of the GI through my business? What type of values can create my business (organization) working on GI?	Ecosystem Service -> Generates -> Values

Key Activities	The activities related to GI, and that interacts with the GI. The activities related to GI, and that interacts with the GI.	What activities related to the GI will be improved, enabled, or supported?	GI management, educational activities, local products promotion.
Key Resources	The resources, both human and natural on which the business is based on.	What are the resources you need to make your activity working? How can you obtain them?	GI, funds, know-how, personnel.
Key Partners	All the partners that cooperate with the organization.	What are the stakeholders that contribute to activities on GI?	Other stakeholders that cooperate with the activity such as companies, public administration, citizens and NGOs.
Key Beneficiaries	Beneficiaries that are connected to the organization.	Who are the beneficiaries of your activity on GI?	All the beneficiaries: citizens, PA, collectivity.
Governance	The set of policies and plans that constitute the local governance.	Who are the agents interested in the GI? How is it managed? What are the tools to plan and program? How do interact with our activities?	GI management and planning: plans and politics.
Channels	All the channels on which the products or service are sold.	How can we reach our clients and our organization's targets? Through which channels? How can we integrate different channels?	Direct sale, cooperation with PA.
Customer Segments	All the targets that are in the organization range.	Who are the beneficiaries who are, or can become, clients, supplier, end-users of my value-creating activity?	Shops, PA, citizens, organizations.
Cost Structure	The architecture of costs of the organization.	What are the main items of expenditure? How will you cover the costs? How will the beneficiaries pay products or services of our activity?	Expenses and type of costs.
Value Capture	The kind of values and to whom they are generated.	What type of value will create your activity? How can it be measured? How will it be economically sustainable?	Economic Value, Environmental Value, Social Value.
Socio-ecological Harms	The different harms that are present in the organization.	How does your activity create negative consequences on the socio-ecological context in which it operates? What are these consequences? How do you reduce them.	Reduction of ecosystem services and damages to local ecosystems, scarce consent of the local community.

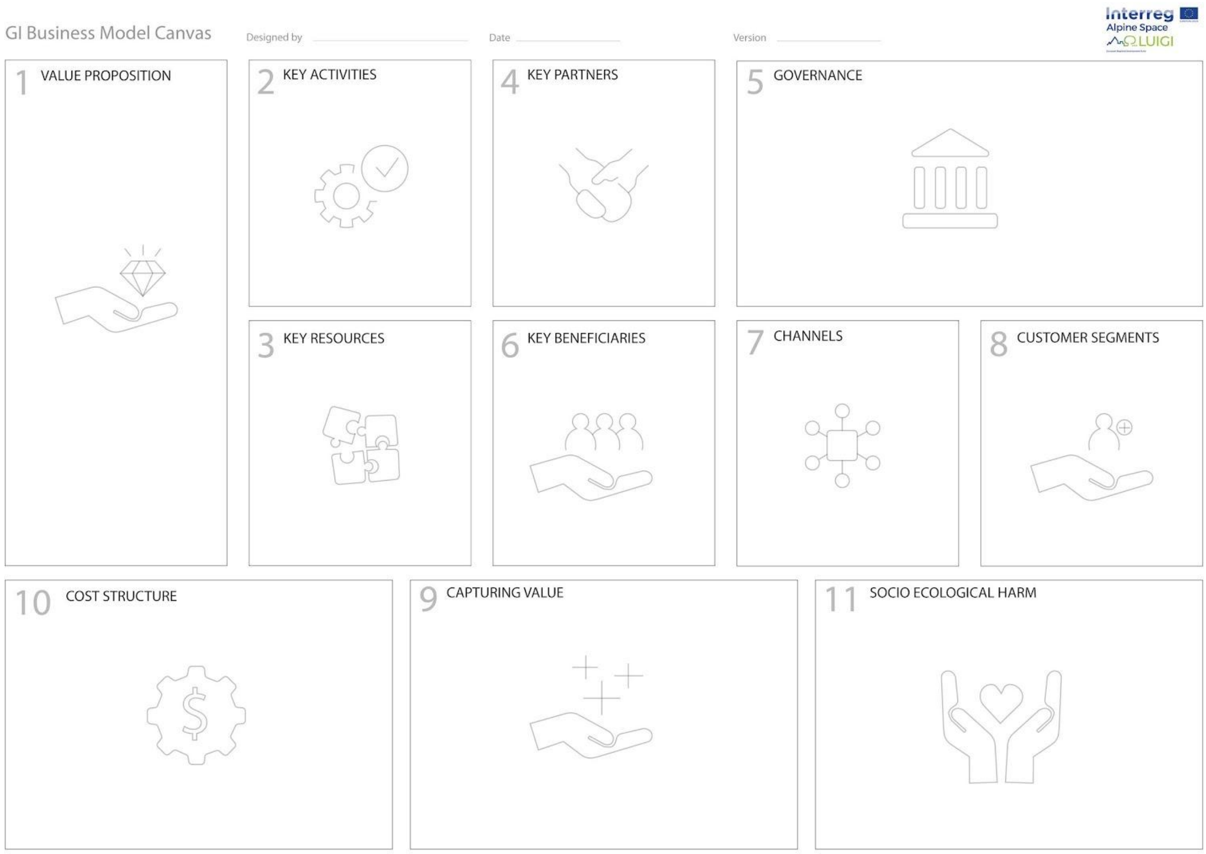

Figure 8. The GI BM canvas from LUIGI project

So far, NbS and GIs are presented as two major examples of the application of BM innovation theory to ecosystem-based contexts, from which interesting categories can be drawn for a focused application to the analysis of the FES from the FEV LLs. However, the final selection will also take into account other valuable sources from literature and practice more focused on sustainability and the circular economy in general (Bocken et al., 2014; Lüdeke-Freund et al., 2018; Schroedel, 2023).

Aims of BMs for the enhancement of FES in FEV LLs

Now, the reasons have been shown why BMs would seem a sensible tool for bringing innovation in the field of forest management and marketing services from forest ecosystems formerly seen as unfit for any type of trade.

By using appropriate BMs in the FEV LLs, the aim is to facilitate the trade of FES, especially of those services that are different from timber provision, by using innovative approaches aligned to the BMI theory.

In particular, aligned with the discussion introduced earlier in this paper, we observe that:

1) Several benefits from FES are hardly perceived by beneficiaries or require a longer period of time to materialize,
2) Several FES are essentially PGs and suffer from lack of excludability, and the subsequent consequences in terms of under-/inefficient provision.

Against the issues raised in 1) and 2), BMs can help develop methods to:

a) identify, disclose and convey FES benefits to interested groups of beneficiaries (1), and

b) frame payment schemes or arrangements to increase the supply of PGs, including by incentivizing their private provision (2).

So far, apart from few exceptions, there is a lack of literature and case studies of specific BMs addressing ESs and especially FES. In addition, BMs expressly framed to address benefits and opportunities deriving from the natural environment or landscape to companies, people or communities are limited (though some applications recently addressed the cases with NbS and GIs, and a few other compatible situations).

More attention has been paid by BM literature to successful payment schemes for PGs or for goods and services sharing some typical features of PGs, such as problems with excludability or perception by customers. Many lists of BMs and schemes exist in scholarly business literature, describing how to set up payment schemes or other commercial or institutional arrangements for a diverse set of goods and services. Particularly effective in conveying simple and focused information for entrepreneurs and innovators are the so-called *BM archetypes, i.e*. representations of an organization's value logic, detailing how it creates and captures customer value. Usually, alternative BM archetypes (BMA) differ from each other in value creation methods, objectives, value creation mechanisms, and infrastructural and technological requirements.

A BMA is defined as a pre-defined pattern that describes how a company creates, delivers, and captures value. A BMA in practice often takes the shape of a template or framework that identifies the *core* elements of a single business, but it can also be widened in order to include more specific or contextual features. Some distinctive elements considered in the typical description of a BMA are reported in Table 22. Others can be added, depending on the purpose of the analysis conducted: this is typically the case with sustainability, circularity, GIs, or NbS. Here, the goal is to construct a special framework for BMAs, also for FES-based economic initiatives.

Table 22. Elements considered in a Business model archetype (own elaboration on Gassmann et al. 2014)

BMA constitutive elements	**Intuitive description**
Products or services	What is offered by the organization/firm?
Customers	Who are the customers of the supply of the organization/firm and what are their needs?
Value proposition	Why should customers choose this company?
Value creation / Value chain	How does the company create value for its customers?
Revenue streams / Profit mechanism	How does the company make money?

All BMs can be described by the combination of those or other similar dimensions, such as the customer, the value proposition, the value chain, and the profit mechanism (Gassmann et al. 2014). Based on those four essential elements, it is possible to define several distinctive applications of this BMA: each focuses on a specific situation where a firm/organization operates, described according to the same list of constitutive parts recalled above.

Against the background framed here above and based on the FES identified for each of the FEV Living Labs (LL) and an analysis of a selection of their features (biological, institutional, and economic ones), **the goal is to define a *shortlist* of BMs suitable to address their supply or trade, and bring about some exemplary case studies in support of them. The resulting shortlist will then be presented and made available with adequate materials to the PPs operating within and coordinating the FEV LLs.**

Methodology

In order to achieve significant innovation through the introduction, application, and refinement of BMs in the relatively unexplored field of FES provision, we adopt a procedure based on the results achieved in the framework of FEV under two main dimensions:

1) the biological dimension of FES as analyzed within WG BIO;
2) the market dimension of FES as analyzed within WG ECO and namely in the WG ECO Template for FES market assessment, Business Model Canvas, and BM template collection data, including also a relevant institutional and governance element.

The whole procedure is made up of a series of steps aimed at establishing a link between:

- a selection of biological, market and institutional/governance features associated to a given FES in every LL, and
- a BM archetype.

Therefore, the methodological procedure is framed as follows:

Step 1: Identification of relevant features and concepts for LLs and FES

Step 1 includes the identification of a shortlist of relevant **concepts** characterizing each Living Lab (LL), representing the combination of ecological, governance, economic, and market conditions framing the local context for the potential development of Forest Ecosystem Services (FESs) markets.

These concepts will be selected through literature review, good practice analysis (especially across Europe in the forest sector), and expert assessment, and are considered essential to frame the local enabling conditions for FES-related Business Models (BMs).

Each LL is thus represented by a set of seven concepts, each potentially described by up to three indicators, whose value determines the concept intensity.

Step 2: Identification of a shortlist of BM archetypes suitable for FES

Assuming that FESs typically frame contexts where PGs are supplied, *BM archetypes* addressing the following arrangements/mechanisms of supply are considered, as presented for NbS, GIs, and other similar cases against the supply of public goods: *public provision, mixed provision*, and *private provision*.

Step 2.1

Each BMA will be characterized according to the presence and **intensity of the LL concepts** required for its proper functioning.
The assessment of the relationship between LL concepts and BMAs will be performed through two parallel methods:

1. **Automatic statistical weighting** using an **entropy weighting technique**, which assigns data-driven weights to each concept for each LL.

2. **Expert-based assessment**, in which experts rank the relevance of each concept for the local implementation of each BMA.

The final weight assigned to each concept combines both approaches by assigning preference to expert-based over statistical weighting.

Step 2.2

For each LL, all indicators representing the seven concepts will be collected by local coordinators or from official statistics.
Values will be **normalized** to ensure comparability between different measurement units and scales (from physical dimensions, e.g. hectares, to qualitative assessments such as Likert scales).
Indicators have to be aggregated into concept scores, and concept values were normalized again across LLs to establish a consistent numerical basis for comparison.

For each *archetype*, clarification is provided regarding its contribution to the provision (and type) of PGs, and remuneration mechanisms for the provision, as shown in the following table. For better referring to the type of PGs' provision, more details can be retrieved from the further distinction of the remuneration, and more generally speaking, management mechanisms by model of governance[23].

Those BMs will be classified against *a mix* of distinctive features resulting from a selection of:

- a few core-categories that clearly refer to the provision of PGs: the *type of providers* (private, public, mixed) of FES, the *excludability conditions* for the service supplied, the *governance model* adopted[24], and the *remuneration mechanism* used,
- A few categories used by the classic BM canvas and its adjustments
- A non-exhaustive list of categories – from the two types of categories mentioned above – drawn from literature and particularly BM canvas for GIs and NbS, characterizing potential BMAs are reported in the table below.

Table 23. Exemplary categories used to describe a BMA.

Macro-category	Sub-categories
Excludability conditions for FES	Public Good
	Club Good
	Global Commons
	Private Good
Value proposition	Environmental VP
	Economic VP
	Social VP
	Trade-offs
Value creation and delivery	Key activities
	Key resources
	Key Partners
	Key Beneficiaries
	Intermediaries
	Key Channels
Value capture	Cost Structure

[23] Sources for identifying possible BMs include the Sustainable Business Model archetypes - SBM (Bocken et al., 2014), the Green Infrastructure Business Model archetypes (LUIGI, 2021), and lists of other BMs from different sources.
[24] Governance models may refer to a set of arrangements as the five ones recalled when dealing with management and funding NbS: Traditional Public Administration; New Public Management; PPPs and externalisation of services of public interest; Private-private partnerships; Societal resilience; and Network Governance.

	Cost Reduction
	Revenues streams
	Capturing Value
Financing upfront costs	Capital Expenditure Costs
	Sources of Capital Investment
Governance	Public
	Private
	Mixed
	Model
Customer Segments	a)
	b) …
Socio-ecological Harms created	

The resulting descriptive categories are reported at the top of the columns of the table 24 below.

Table 24. Descriptive categories (PGs' provision categories and BM canvas categories) of BMs for FES

BM archetype	**Type of PGs' provision** (PU, MI, PR)*	**Excludability conditions**	**Governance model**	**Remuneration mechanism(s)**	**Cost structure**	**Value proposition**	**(…)**
(…)							

*PU: public, MI: mixed, PR: private

Step 3: MCA–TOPSIS analysis and ranking

By setting up a matrix where all the BIO and ECO categories that characterize FES and BM archetypes are listed, a degree of coherence between the lists (or suitability) will be calculated.

In order to assess a coherent *suitability score* between each FES and one or more BMs, while establishing some useful thresholds, a consistent matching technique is needed.

A well-established methodology used in the literature to face complex decision-making processes is the Multi-Criteria Decision Analysis (MCDA). MCDA is a non-monetary approach whose output is a coherent raking of multiple alternatives reflecting their suitability towards an indicator or evaluator.

The MCDA is a versatile methodology that suits thousands of possible decision-making processes and, like other non-monetary approaches, it is considered especially useful in the valuation of ESs, as it enables subjective value judgments about the weights of different options and trade-offs between different ESs.

A Multi-Criteria Analysis combined with the Technique for Order Preference by Similarity to Ideal Solution (MCA_TOPSIS) method will be applied to estimate the **degree of similarity** between LLs and BMAs. Each LL's concept values (weighted as described above) will be compared to the ideal solution — the combination of maximum values observed among all LLs and BMAs.

For each BMA, the distance between the LL's concept values and the ideal solution will be calculated. This allows estimating a **similarity index** between each LL and each BMA, leading to a **rank of BMAs for each LL** according to their degree of suitability.

Step 4: Results interpretation and support to decision-making

The resulting rankings allow identifying which **BMAs best fit** each regional context (LL).
In addition, for each LL, the analysis provides insight into which **concepts** contribute most to the final ranking, offering **targeted suggestions** for improving local conditions or for facilitating the implementation of desirable BMs.

The methodology thus supports decision makers, institutions and forest operators by indicating:
a) which BMAs are most suitable for each LL, and
b) which specific local conditions (concepts) can be strengthened to improve the feasibility or performance of selected BMAs.

Additional materials

Aiming at the identification or elaboration of new BMs specifically tailored on FES, or at the application of existing BMs or BMAs to specific FES in the LLs, some existing materials and operational tools can be used, depending on the purposes of involved local stakeholders.

Particularly, adopting the following frameworks shows significant consistency with the themes investigated in the FEV project, referenced below in table 25.

Table 25. List of other useful materials to be used in LLs for the introduction, test and development of business models for FES.

Framework	**Description**	**Source or link**
The business model canvas	A strategic management and entrepreneurial tool that allows to describe, design, challenge, invent, and pivot a business model. This method is applied in leading organizations and start-ups worldwide.	https://www.strategyzer.com/library/the-business-model-canvas
The NbS business model canvas	The Nature-Based Solutions Business Model Canvas is an easy-to-use tool to help you capture in a visual format the business model of your Nature-Based Solution (NBS).	https://connectingnature.eu/nature-based-solutions-business-model-canvas
The GI business model canvas	The LUIGI GI-based Business Model Canvas is an experimental tool combining the Osterwalder and Pigneur's	LUIGI ASP Project

	original BMC with the Sustainable BMC and the NBS Canvas. It aims to disclose the economic opportunities deriving from a comprehensive view of GIs.	
Manual for conducting focus groups and consideration on the marketing of “Green Infrastructure“	It provides instructions for conducting simple market research on GI products and services. For this purpose, it introduces the "focus groups" method (see chapter 3) and then explains it using a concrete example	LUIGI ASP Project – FIBL, 2021

Conclusions and next steps

Some authors believe that all business models are made up of two parts: one – the *internal* – includes information on a company and its internal operations; the other – the *external* – always refers to the market where the company acts.

All this information (internal & external) can be classified – though in a simple version – within the business model canvas (BMC), where there is room both for idiosyncratic information on the unique company involved, and for microeconomic information on the markets where the company could operate and their distinctive structures and features.

Though very generically put in a BMC, such information can be highly refined in other documents that are typically required for start-ups and innovative projects for which finance is needed, the most classical of which is the “business plan”.

Against this background, the exercise proposed for FEV in its LLs aims at achieving a convergence of market conditions and business special features, operations, and strategic innovation approach.

More precisely, the exercise links a set of market conditions as found in a specific region or Living Lab (that defines a context for a set of forest ecosystem services, and describes the market and wider socioeconomic landscape compatible with the FES under investigation) to a business model archetype (here, a sort of general mechanism to deal with value proposition, delivery, capture, etc. referred to multiple value types, including ecological and social ones).

Moreover, it provides some examples of FES and ES markets on the one hand, and of business models on the other, intending to support the use of a special, adjusted version of BMC inspired by the Nature-Based Solutions Business Model Canvas (McQuaid et al., 2019), for launching or refining business initiatives within the investigated regions (or in other regions sharing similar features to the original one).

Concretely, most market conditions as presented in the FES market assessment section of this analysis directly refer to specific categories used in the Nature-Based Solutions Business Model Canvas. Moreover, on the market side, the information collected in the Living Labs as elaborated in our model primarily based on Wunder (2008), allows either identifying a suitable market-based instrument or mechanism to implement a regional FES market where no markets exist yet, or finding the conditions that should be strengthened to ensure a better functioning of a tentative regional market.

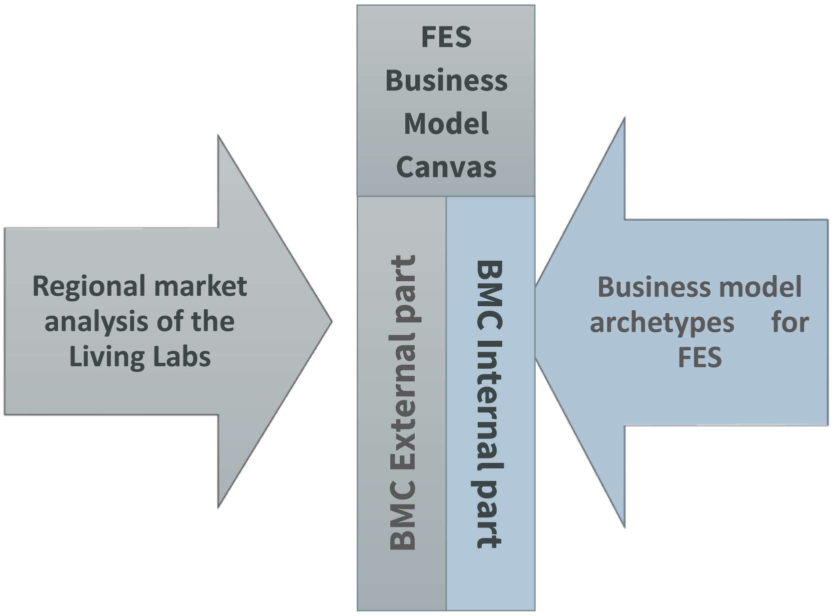

Figure 9: Convergence of analytical results into the FES Business Model Canvas (own elaboration).

As shown in Figure 9, the FES Business Model Canvas is fed on one side by the regional market analysis that defines the external part of the BM, on the other side by the business model archetypes addressing goods or services sharing some distinctive characteristics with forest ecosystem services. The result is a regionalized guide to setting up innovative mechanisms for FES enhancement based on specific market conditions and business environments.

In each Living Lab/region only local FES as selected within the FEV project are considered when developing the guide.

It is worth mentioning that the market and business conditions analysis provided by the combination of the regional market analysis and the Business Model Canvas categories represents a base for identifying policy gaps, inefficiencies, or needs that will be better presented in the policy section of the project.

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