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ORIGINAL ARTICLE

Efficient forest policy design under the EU Green Deal: aligning ecosystem service potential with public values

Kaja Plevnik[1,2] · Anže Martin Pintar[2] · Anže Japelj[2]

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Abstract

The efficient implementation of forest-related policies under the European Green Deal requires assessing the capacity of ecosystems to deliver ecosystem services (ES) and involving stakeholders in the decision-making process. Public involvement ensures that policies align with local needs, relevant ES are identified, ES supply is optimised, and acceptance of measures is increased. We conducted a nationwide public survey ($n = 813$) in Slovenia, consisting of three sections: (1) knowledge and perceptions related to ES and the bioeconomy, (2) a discrete choice experiment (DCE) to elicit preferences for possible changes in the supply of forest ES and products based on them (FPS) that support the strategic objectives of the EU Green Deal, and (3) questions on socio-demographics, lifestyle, and consumer behaviour. The results of the DCE, together with respondents' place of residence using Moran's I statistic, allowed us to identify areas of distinct preferences (ADP), either positive or negative, for FPS. Based on biophysical indicators, we assessed the potential supply of FPS within and outside ADP and found statistically significant differences. Then we compared potential supply with public preferences (demand) for FPS, which yielded several findings, most notably three cases where higher potential supply of FPS within the ADP coincided with positive preferences in the same ADP: high-quality wood, strictly protected forests, and forest tourism involving non-owners. In all these cases, mobilising additional FPS would benefit communities within the ADP (meeting allocative efficiency), and their high potential supply makes this feasible as well (meeting resource use efficiency).

Keywords Forest ecosystem services · Public preferences · Potential ES supply · Spatial matching · EU forest-related policies · Policy efficiency

✉ Kaja Plevnik
kaja.plevnik@gozdis.si

Anže Martin Pintar
anzemartin.pintar@gozdis.si

Anže Japelj
anze.japelj@gozdis.si

[1] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana 1000, Slovenia

[2] Slovenian Forestry Institute, Večna pot 2, Ljubljana 1000, Slovenia

1 Introduction

The European Green Deal is an ambitious attempt to steer the European economy towards a model of climate neutrality that is environmentally sustainable, socially just, and economically fair (EC 2019). Officially adopted in 2020, the Green Deal has undergone extensive debate and has led to the development of strategic initiatives and subsequent operational policies. Due to their broad objectives, these policies are intended to immediately affect several key economic sectors such as agriculture, forestry, water management, construction, and transport. However, the role of natural resources in the green transition can be contradictory in terms of significant societal needs and limited ecological capacities. Continued reliance on fossil fuels is clearly counterproductive, as is the over-reliance on consumers to drive the transition to renewable resources (Cseres 2021). Combined with unsustainable resource use and the risks posed by climate change, this highlights the need for an inclusive approach that involves all key stakeholders, as emphasised by the EU Bioeconomy Strategy (EC 2018), which is a key component of the Green Deal. The strategy calls for the substitution of fossil resources with those of natural origin, directly influencing their supply and demand (Liobikienė and Miceikienė 2023). This is particularly evident in the case of forest resources, where the diversity of ecosystem services (ES) and the associated products and services is greater than in other ecosystems, and the range of stakeholders is equally wide (Weller and Elsasser 2018; Grammatikopoulou and Vačkářová 2021). This requires efficient resource use and allocation to facilitate the EU green transition (Cuadros-Casanova et al. 2023), thereby reducing planning and implementation errors in the mechanisms designed by Member States to achieve the Green Deal's objectives. In this context, efficient support for the provision of ES is key to sustainable development, societal well-being, and the use of ecosystems within their ecological limits. This leads to the non-wasteful use of resources to meet human needs (Baumgärtner et al. 2012). Several elements contribute to this outcome: stakeholder involvement, effective management measures, and the integration of ES into the design of operational policies (Cowling et al. 2008). Ignoring all or even some of these elements can result in the failure to assure the continuous and sufficient supply of ES (Cabral et al. 2017).

Engaging stakeholders in defining the optimal supply of ES offers several benefits. It helps focus attention on relevant ES (Schoonover et al. 2019), define the point where societal needs are met by sufficient availability of ES (optimal supply of ES), and ensure the acceptability of actions aimed at improving the state of ES (Martinez-Harms et al. 2015). Stakeholders, especially local communities, possess valuable knowledge of their surrounding natural and managed environments. This knowledge can be used to make reliable, environmentally sustainable, and socially equitable management decisions (Lavorel et al. 2017; Mosleh et al. 2023). Such approach is central to community-based management (Dreoni et al. 2022).

Access to information on the supply and demand of ES within a given spatial and temporal context is essential for informed decision-making. Comparing human needs for ES and nature's capacity to supply them enables the assessment of sustainability. It also helps to identify the risks of surpassing ecological limits. Furthermore, integrating ES into policy is vital when managing the competing demands of multiple stakeholders (Kieslich and Salles 2021), which requires aligning multidimensional and sometimes conflicting policy objectives (Harrison et al. 2010) like trade-offs among provisioning, regulating and cultural ES.

Finally, understanding supply and demand enables efficient resource allocation and maximises societal benefits (Lü et al. 2012), especially when ES supply and demand can be mapped (represented) spatially.

A common element of such informed decision-making is the evaluation of ES (De Groot et al. 2002; Daily et al. 2009; Maes et al. 2013). Mapping and modelling ES are critical tools for their evaluation and contribute to their recognition and use (Daily and Matson 2008). Since many ES are public goods, having socially constructed, publicly accessible information about them is essential for effective decision making (Dryzek 2002). Participatory approaches are therefore crucial, as they can capture and incorporate local management practices (Mosleh et al. 2023), traditional knowledge, and cultural beliefs. This ensures that stakeholder values and preferences are recognised, leading to more legitimate and effective nature conservation actions, as well as fairer and more sustainable outcomes (Dobričić and Sekulić 2020). Furthermore, ES modelling and mapping can identify areas with high capacity to provide one or more ES across landscapes (Duarte et al. 2016). Spatially based assessments are thus vital for sustainability (Potschin and Haines-Young 2013), as identifying ES “hotspots” can guide policymakers in choosing when, where, and how to implement rational, sustainable, and equitable management actions (Benabou et al. 2022). This enables efficient support for ES, as human and material resources can be assigned to areas with the highest potential.

In our study, efficiency of support to ES has two elements: (1) resource use efficiency and (2) allocative efficiency. Smart use of limited resources (materials and energy) per unit of ES means optimising the use of resources and provision of goods and services (Sachs and Santarius 2007), while allocative efficiency refers to assigning resources to their best societal use – that is, where they matter most (Daly 1992). Within the ES framework and the ES cascade model (Haines-Young and Potschin 2012; Zhang et al. 2022), efficiency relates both to the supply (stock) of ES and the demand (benefits and their value). Evaluating ES can inform both. Assessing ES supply reflects an ecosystem’s capacity to generate ES (Daly 1993), while valuation of benefits and attributed values reflects societal demand (Schröter et al. 2017). This links back to the two types of efficiency. First, information on nature’s ability to provide ES reveals where and when resource investments can achieve the highest ES supply. Second, understanding public preferences for ES indicates how people value benefits, and which groups would experience the greatest gains in well-being. When this information is spatially explicit, it further enhances the efficiency of support for ES supply. It enables decision-makers to link the locations of stakeholders to whom use of ES matters most with the areas of highest ES potential. Based on this, they can prioritise interventions that align with both ecological integrity and human well-being.

Previous research on evaluating supply-demand relationships has largely focused on provisioning ES, such as water yield, wood and energy from biomass, and food supply (Morri et al. 2014; Lin et al. 2021; Chen et al. 2024; Kpienbaareh et al. 2024; de Knegt et al. 2025; Gao et al. 2025a; Garcia et al. 2025; Shen et al. 2025). Extensive research has also addressed regulating ES, including carbon sequestration, habitat quality, soil conservation, soil retention services, soil fertility, erosion prevention, water purification, air quality regulation, pest control, and pollination (Morri et al. 2014; Kpienbaareh et al. 2024; Lin et al. 2024; de Knegt et al. 2025; Gao et al. 2025a; Shen et al. 2025). A growing body of research has focused on the cultural ES supply-demand ratio, examining recreation, natural heritage, the symbolic value of nature, aesthetics, leisure, spiritual services, and ecotourism (Zhao et al. 2023; Dang et al. 2024; Wang et al. 2024; You et al. 2024; Zhang et al. 2025). In many of these studies, especially those concerning provisioning and regulating ES, researchers have applied models (e.g. InVEST) or other calculation methods based on existing statistical data (e.g. food consumption (kg/person), per capita carbon emissions). To measure cultural ES demand, researchers have used participatory geographic information systems (GIS) mapping, social media data, expert assessments, and behavioural observations. Similar methods have been used to measure provisioning and regulating ES supply, including calculations based on available statistical data (e.g. carbon storage, annual water yield, annual precipitation, annual food production, above- and below-ground biomass), normalised difference vegetation index (NDVI), revised universal soil loss equation (RUSLE), and models such as InVEST. Cultural ES supply has been evaluated using models such as the Social Values for ES model (SoLVES), natural language processing topic models, participatory GIS mapping, questionnaire data, replacement cost methods, and spatial carrying capacity assessments.

What remains underexplored is a country-tailored approach that aligns the demand for ES based on people's actual needs with the corresponding ecosystem supply. Our research addresses this gap by focusing on forests and building a comprehensive understanding of public preferences for additional forest ES and products based on them (hereafter FPS), which can be linked to several key forestry-related policies of the European Green Deal, along with the capacity of forest ecosystems to provide them to a greater extent.

In the Slovenian national context – characterised by one of the highest forest cover rates in the EU (58.2%), highly fragmented, predominantly small-scale private forest ownership, and a long tradition of multifunctional and close to nature forest management (Diaci and McConnell 1996) – we hypothesise that (1) public preferences for FPS are heterogeneous and depend on socio-demographic characteristics. This relates to the allocative efficiency of policies designed to support the potential supply of FPS for the public groups that would benefit most. Furthermore, we expect that (2) the potential supply of FPS does not fully align with public preferences. Identifying mismatches between potential supply and demand is therefore essential, as it indicates where investment is needed to improve the capacity of forest to efficiently supply FPS.

Our study will review European Green Deal policies relevant to FPS and highlight the most pertinent ones to Slovenia. We will investigate public preferences for FPS, identify the ecosystem's potential to supply them, and ultimately determine where intervention into FPS would be most efficient.

In doing so, our research will provide a pilot approach for possible elaboration of the national bioeconomy strategy (EC 2025), to inform the development of national restoration plans (due 2026) (Ministry of Natural Resources and Spatial Planning 2025) under the EU Nature Restoration Regulation (EU 2024), and to support the implementation of the EU Biodiversity Strategy (EC 2020) and the EU Forest Strategy (EC 2021). All of these efforts depend on clear, spatially explicit information about what FPS people need, and where ecosystems have the capacity to provide them.

2 Materials and methods

The methodological approach follows four key steps:

1) A quantitative public survey was conducted to collect data on people's preferences for several FPS (reflecting demand) using a discrete choice experiment (DCE).
2) The identified preferences were then used to spatially define clusters of municipalities (using Moran's I statistic) representing areas of distinct preferences (ADP) for FPS.
3) The potential supply of FPS within ADP was compared to the potential supply outside these areas (statistical tests of difference).
4) FPS cases were categorised into four different combinations (using the four-quadrant method) of potential supply and demand for FPS, providing guidance for future forest management.

The study started with a systematic review of EU forest-related strategic documents (EU Biodiversity Strategy (EC 2020), EU Forest Strategy (EC 2021), and EU BE Strategy (EC 2018). In collaboration with 13 experts from forestry, BE, biodiversity protection and ES, we identified objectives relevant to the Slovenian context, categorising them into ES groups from which we derived attributes that define the FPS specific to Slovenia (Table 2).

2.1 Survey and data collection

The first part of the study is based on a nation-wide survey of the Slovenian public, with a population of 2,126,324 (SURS 2022). The data were collected via an online questionnaire administered by a professional market research agency using an online panel in April and May 2023. Respondents were selected using a stratified recruitment process based on age, gender, and place of residence. For each respondent, we collected demographic data including age, gender, education level, place of residence, employment status, and forest land ownership. The ratio of the age and gender of the population was chosen to be representative at the national level. In addition, the market agency was tasked with maximising spatial dispersion by collecting responses from as many Slovenian municipalities as possible. As our research focused on the general public, we excluded forest owners from the survey to avoid bias in the responses.

To assure representativeness, we compared our sample with national demographic statistics (Table 1). Our sample was largely representative in terms of gender and age distribution, except for individuals aged 75 and over, who were underrepresented, a common issue in online surveys, as older people are generally harder to reach on-line.

About half of the respondents (51.3%) live in urban areas, while the other half (48.7%) live in rural areas. In addition, 56.50% are employed and 32.2% are retired. Slightly less

Table 1 Gender and age structure: comparison between the general population and the survey sample, with statistical tests for structural differences

Characteristic	Population (SURS 2022)	Sample (n=813)	Proportion Test (p-value)
Gender (male)	871,949 (50.7%)	395 (48.5%)	0.420
Age			
<30 years	243,376 (14.1%)	124 (15.2%)	0.304
30–44.9 years	434,600 (25.3%)	206 (25.3%)	0.824
45–59.9 years	451,983 (26.3%)	205 (25.2%)	0.610
60–74.9 years	399,832 (23.2%)	208 (25.6%)	0.080
75 years and over	191,224 (11.1%)	70 (8.6%)	**

Significance levels: *p<0.1, **p<0.05, ***p<0.01

than half have a secondary education (46.7%), 22.5% have completed tertiary education, and 27.8% hold a bachelor's degree or higher.

The questionnaire began with general questions assessing respondents' knowledge of the concepts of ES and BE, followed by a series of statements related to various FPS and the potential impacts of European policies for BE, forestry, and biodiversity protection. Agreement with these statements was measured using a Likert scale (Joshi et al. 2015). The questionnaire was supplemented by questions on the respondents' lifestyle (frequency, purpose of forest visits) and consumer behaviour (purchase of wood products). These three sets of questions also helped respondents familiarise themselves with the content that was later included in the DCE. The central part of the questionnaire consisted of the DCE, in which respondents could express their preferences regarding hypothetical changes in the supply of FPS. The questionnaire concluded with questions on socio-demographic data, including gender, age, and personal income.

2.2 Discrete choice experiment

The discrete choice experiment (DCE) is a stated preference method based on Lancaster's (1966) theory and the Random Utility Model (RUM), which assumes that utility derives from the attributes of a good (Hanley et al. 2001; Bateman et al. 2004). Respondents choose among alternatives defined by different attribute levels, often including a status quo and a monetary attribute, allowing estimation of willingness to pay or accept (Adamowicz and Boxall 2002; Hensher et al. 2015). Choices are commonly analysed using the Multinomial Logit (MNL) model, which relies on the IIA assumption (Luce 1977; Louviere et al. 2000), though more flexible models such as Random Parameter Logit or Latent Class Logit can account for preference heterogeneity and relax IIA (McFadden and Train 2000; Hensher et al. 2015).

2.3 Experimental design

The DCE was designed based on the strategic EU policy objectives and derived attributes (Table 2). Thirteen domestic experts mentioned earlier were involved in linking these objectives to the FPS. These were then defined as attributes with varying levels, which were used in the DCE (Table 2). The current status of these attributes was determined using data from forest management plans and other sources provided by the SFS. Prior to the DCE, these attributes were described in detail in the questionnaire, and their full presentation can be found in Appendix A.

The experimental design included five attributes with three levels each and one attribute with six levels, resulting in 1,458 possible combinations ($3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 6$). Due to this large number, a full factorial design was not feasible, so we used a Bayesian efficient design based on preliminary values from a pilot survey. This pilot survey was based on sequential fractional factorial design and was conducted in October 2022 on a sample of 255 respondents (39 responses were excluded due to repeated protest responses). Based on the MNL model estimates from the pilot study, we developed a final experimental design optimised for D-efficiency in the MNL model (Choice Metrics 2024). The final design consisted of 36 choice sets, divided into four blocks of nine choice sets each. Accordingly, there were four versions of the questionnaire, which were randomly distributed among the

Table 2 Links between the strategic goals of EU forest-related policies, ES categories (classified using common international classification of ecosystem service (CICES) (Haines-Young and Potschin 2018), and FPS included as attributes in the discrete choice experiment (DCE). Attribute levels used to model different policy scenarios and the corresponding variable types are also presented

Strategic goals of EU forest related policies	ES Using CICES	FPS /As attributes in DCE	Attribute Level	Type of variable
Replacing carbon-intensive materials with long-lived wood products	Provisioning	High-quality wood	50 [1] 60 70 (% of wood harvested from private forests that can be used for high-quality wood products)	Continuous
Adaptation to climate change	Regulation & maintenance	Non-native tree species	0.4 [1] 2 3 (% of Slovenian private forests area planted with non-native tree species.)	Continuous
Promotion of other sectors of the BE and creation of new green jobs	Cultural	Forest tourism	Unregulated [1] Forest owner engaged in tourism. Somebody else engaged in tourism.	Categorical
Biodiversity conservation	Regulation & maintenance	Strictly protected forest	0.3 [1] 5 20 (% of Slovenia's private forests that are strictly protected.	Continuous
/	/	Control	No control system [1] Activity recording Activity effects check	Categorical
/	/	Yearly payment	0 [2], 20, 40, 60, 80, 100, 120 EUR/ha	Continuous

[1] attribute level reflects the current state that could occur in any alternative; [2] attribute level reflects the current state that could occur only in the status quo alternative. Other levels reflect increased FPS supply as a result of additional measures, supported by a voluntary public payment

respondents. Each choice set contained three alternatives: one representing the status quo and two representing alternative scenarios, reflecting possible changes if certain actions were implemented. An example of a choice set is provided in Appendix B (Fig. 12).

2.4 The choice model

Using the attribute definitions, we formulated the deterministic part of the utility function as follows:

$$V = \beta_0 + \beta_1 x_{wood} + \beta_2 x_{nonnative} + \beta_3 x_{tourism} + \beta_4 x_{protect} + \beta_5 x_{control} + \beta_6 x_{payment} + \epsilon$$

The modelling was carried out using all six attributes, which were treated as independent variables. The attributes ‘high-quality wood’, ‘non-native tree species’, ‘strictly protected forest’, and ‘annual payment’ were treated as continuous variables, while ‘forest tourism’ and ‘control’ were treated as discrete variables with three possible levels. The WTP of the respondents was calculated according to the formula: $WTP = -\frac{\beta_k}{\beta_c}$, where β_k is the coefficient of attribute k (k = 1, …,4) and β_c is the payment coefficient. Mean WTP values and their 95% confidence intervals were calculated using the Delta method (Greene 2012). Prior to estimating the model, protest responses ($n = 105$), where respondents selected the status quo option nine times in a row, were removed from the dataset. The analysis of responses (i.e. choice of alternatives) was conducted on a final sample of 813 respondents using NLOGIT version 5.

Before selecting the model type, a Hausman test (Hausman and McFadden 1984) of the IIA assumption indicated that this assumption was violated (Table 3). Therefore, we chose a model that allows for heteroskedasticity and does not rely on the IIA assumption—a latent class logit model (LCLM). The LCLM enables classification of respondents into latent classes based on their preferences. Preferences are assumed to be homogeneous within each group but heterogeneous across groups (Swait 1994). The model also allows analysis of the influence of socio-demographic characteristics, opinions, and attitudes on class membership.

2.5 Areas of distinct preferences (ADP)

The results of the LCLM estimation were used to identify spatial patterns in the occurrence of respondents with similar preferences. Each respondent is assigned to a specific latent class, which is defined by a distinct set of preferences. This in combination with data on respondents' residence allowed to construct a representation of preferences for different FPS on a municipality level. The number of respondents from each latent class was used to calculate corresponding percentages, grouping those with identical (positive or negative) preferences for a particular FPS. Thus, municipalities served as the basic spatial unit, while the proportion of respondents with identical preferences in each municipality was the key analytical metric.

To test whether respondents with identical preferences tended to cluster spatially, we used Moran's I statistic in an incremental spatial autocorrelation format to determine the threshold distance at which the z-score reached its maximum, indicating maximum clustering. These distances were then used to create spatial weighting matrices based on Euclidean distance, which were then entered into the Getis-Ord Gi* statistics-based tool in ArcMap 10.8.1 (see Appendix E). A fixed distance approach was used, which is a suitable option for polygon data with large variation in polygon size, as is the case of Slovenia's 212 municipalities that range in area from 6.9 km^2 (Odranci) to 563.7 km^2 (Kočevje) (SURS 2023); see Appendix C, Fig. 13 for illustration).

Where Moran's I indicated significant clustering, the application of Getis-Ord Gi* allowed us to delineate clusters of municipalities with higher-than-expected concentrations of respondents sharing the same preferences. These were defined as ADP. This analysis

Table 3 Hausman test of the IIA assumption for multinomial logit models

Selected Alternatives for the Hausman Test	Test Statistic[1] X^2	p-value[1,2,3]
Omitted alternative: status quo (alt 1)	/	/
Omitted alternative: option A (alt 2)	84.19	0.00
Omitted alternative: option B (alt 3)	106.92	0.00

[1]α = 0.05; [2] degrees of freedom = 3; [3] critical value of the test statistic X^2 = 12.59

was conducted separately for each FPS, resulting in areas with distinct positive preferences (ADP+) and distinct negative preferences (ADP-). Municipalities with no respondents were excluded from the analysis.

2.6 Nature's potential for FPS

Spatially explicit data on public preferences regarding FPS enabled a targeted assessment of the potential of forest ecosystems to deliver those products and services within and outside ADP. We developed a set of biophysical indicators to assess the potential supply of FPS using national datasets (Table 4). We also defined support measures aimed at increasing the supply of FPS, either by improving the nature's output of FPS or by enhancing the capacity of the local community to utilise them. These measures were also reflected in the DCE.

A detailed explanation of the indicators listed in Table 4 is available in Appendix D.

Table 4 Indicators and data used to estimate the potential supply of FPS, along with descriptions of support measures to increase supply

FPS	Indicator	Data used to estimate the indicator	Support to higher supply of FPS
High-quality wood	Share [0–1] of spruce (*Picea abies* L.) wood of construction quality & veneer quality in total growing stock [m^3/ha].	National forest inventory sample plots (Skudnik et al. 2024): circular plots on a 2 × 2 km grid covering the entire country (*N* = 2194 plots from 2022 to 2024).	Forest stand tending to increase the percentage of construction-quality spruce wood.
Non-native tree species	Share [0–1] of sanitary felling [m^3/ha] in total growing stock [m^3/ha] over a 5-year period (2019–2023).	SFS database on annual removals, stands, and compartments (SFS 2024).	Replanting non-native tree species in damaged forest stands to increase resilience to damaging agents.
Forest tourism	Index of landscape attractiveness [0–100] based on five elements (naturalness, water bodies, heterogeneity of land-use, terrain ruggedness, mountain peaks).	Land-use data (MAFF 2024), digital elevation model (SMARS 2024).	Improving skills of forest owners or tourist guides and maintaining infrastructure to increase opportunities for forest tourism.
Strictly protected forest	The share [0–1] of area of preserved forest stands with tree species composition of minor (up to 30%) alteration.	SFS database on forest stands and compartments (SFS 2024).	Protecting forest stands with relatively undisturbed tree species composition to support biodiversity conservation.

2.7 Juxtaposing potential supply of FPS and public preferences

By comparing the potential supply of FPS within and outside ADP to public preferences, we identified four main FPS support scenarios (Table 5). We applied a four-quadrant approach that had already been used in similar studies (Wang et al. 2019; Khosravi Mashizi and Sharafatmandrad 2021; Yu et al. 2023; Lin et al. 2024) and is a common tool for identifying critical situations in terms of ES supply and people's preferences for ES-based products and services. Each quadrant represents a different relationship between preferences and supply, suggesting specific management strategies to support the future supply of FPS.

These combinations reflect a continuum between allocative efficiency and resource use efficiency, as defined in the introductory part of the paper. This framework helps to determine whether policy support is justified and whether it is likely to be effective in increasing the supply of FPS. In Table 5, dark green indicates situations where both types of efficiency are achieved, light green where neither is met, and medium green where only one is achieved. This information allows decision-makers to better allocate resources and implement policies that improve the supply of FPS while meeting people's needs (Fu et al. 2020).

3 Results

3.1 Awareness and attitudes towards FPS and EU-Related forest policies

First, we investigated how familiar the respondents were with the terms ES and the bioeconomy (BE) (Fig. 1). Almost half of respondents were familiar with the term BE (48.1%). A similar share (46.0%) was familiar with the term ES. Respondents were also asked to choose the correct definition of each term from several options. Once again, familiarity with BE proved to be higher than that of ES, with less than half (43.4%) correctly identifying the definition of ES, while almost three quarters (74.5%) of respondents correctly identified the definition of BE.

The questionnaire was followed by four sets of statements, each related to one of the FPS introduced in Table 2 and later included in the DCE. Respondents indicated their agreement with these statements on a Likert scale.

Table 5 Possible combinations of public preferences for more FPS and their potential supply within ADP in terms of efficiency (related to management support for FPS)

		Preferences for more FPS within ADP		Resource use efficiency
		Negative	Positive	
Potential supply of FPS within ADP (vs. outside)	High	**Partially efficient support** (public does not prefer an increase in FPS supply, although it can potentially be higher)	**Fully efficient support** (public prefers an increase in FPS supply, and it can potentially be higher)	+
	Low	**Inefficient support** (public does not prefer an increase in FPS supply, which cannot be matched with APD)	**Partially efficient support** (public prefers an increase in FPS supply, which cannot be matched with APD)	-
Allocative efficiency		-	+	

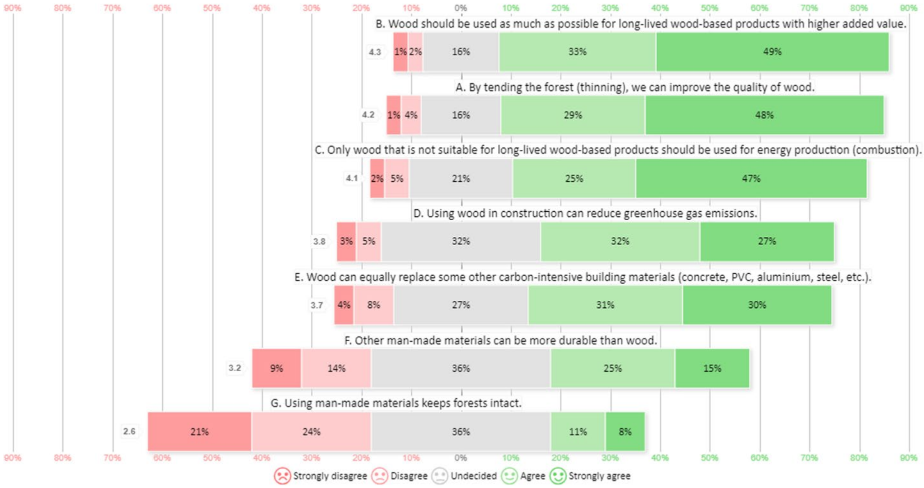


Fig. 1 Respondents' agreement with the statements about high-quality wood

Among the statements related to forest management and high-quality wood, respondents showed the strongest agreement with the following statements: A, B and C (Fig. 1). These three statements all emphasise the importance of high-quality wood as a valuable material. In contrast, respondents showed relatively low agreement with the statements G and F, which consider other man-made materials as durable and more forest-friendly alternatives to wood. Most respondents also agreed that wood can equally replace other carbon-intensive materials in construction and significantly reduce greenhouse gas emissions, as reflected in the statements D and E. This further supports the conclusion that respondents view the use of wood positively.

Responses to statements about non-native tree species indicate a consensus on the need for actions to enhance forest resilience to climate change, even with the help of non-native tree species (Fig. 2). This is supported by a relatively high level of agreement with the statements A and D. At the same time, some respondents reflect caution. The lower levels of agreement with the statements E, F and G. suggest that respondents believe the main role of non-native tree species should not be to increase wood production, but rather to support the forest's adaptability to climate change, which should be one of the priorities of the Slovenian forestry sector.

Respondents also expressed clear and consistent support for forest tourism. As shown in Fig. 3, the strongest agreement was with statement A, with slightly lower but still strong agreement for statements B and C. These responses suggest that forest tourism is widely seen as a valuable economic opportunity and that forest owners should play an important role in its implementation. This view is reinforced by the high level of disagreement with the statement G, which emphasises the importance of other non-wood income opportunities. Responses to the remaining statements were more varied. The mixed opinions on statement D may reflect uncertainty or a lack of information about the specific management adjustments that forest owners would need to implement. While respondents generally recognised the economic potential of forest tourism, some were also aware of its possible negative impacts on natural resources and local communities, as suggested by the responses to D and

Fig. 2 Respondents' agreement with the statements about non-native tree species

Fig. 3 Respondents' agreement with the statements about forest tourism

F. These results point to a nuanced view: while forest tourism is seen as a valuable opportunity, there is also concern about managing it in a way that is sustainable and respectful of the forest environment and local population.

Out of all the statements regarding biodiversity conservation, respondents most strongly and consistently agreed with the statement A (Fig. 4) and they also showed a relatively high level of agreement with statements B and E. These views suggest a broad consensus that biodiversity conservation, particularly through the establishment and protection of forest habitats, should be a key priority. This is further supported by considerable disagreement with the statement F, suggesting that respondents recognise the ongoing need for additional protection measures. At the same time, many acknowledge the challenges that protection regimes can pose to forest owners, as reflected in strong agreement with statement C. There

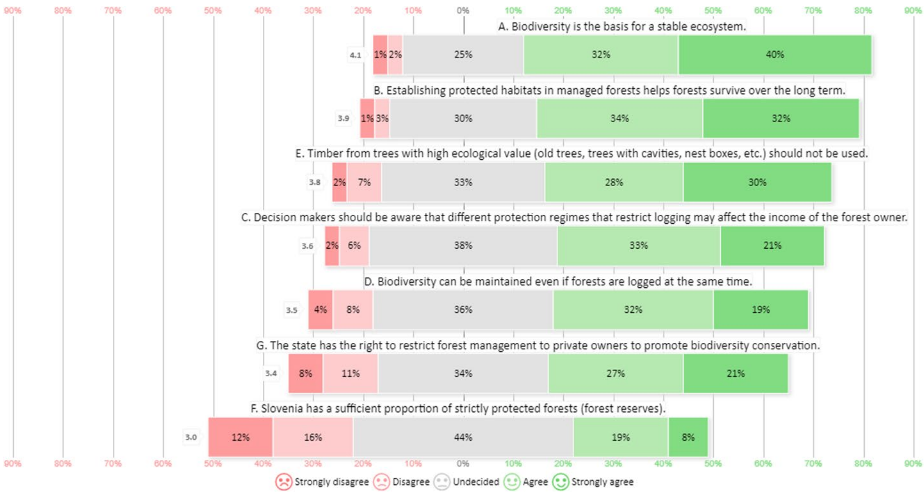


Fig. 4 Respondents' agreement with the statements about biodiversity

Table 6 Test results for the different number of classes in the latent class model

Number of classes	Number of Observations (N)	Number of Parameters	Log-Likelihood (LL)	BIC[1]	AIC3[2]	CAIC[3]
2	7317	19	−6647.55	13368.51	13352.09	13387.51
3		29	−6495.25	13102.57	13077.50	13131.57
4		39	−6409.39	12969.50	12935.79	13008.50
5		49	−6350.94	12891.24	12848.89	12940.24

[1] $BIC = -2 \times LL + (\log(N) \times P)$, [2] $AIC3 = -2 \times LL + (3 \times P)$, [3] $CAIC = 2 \times LL + (\log(N) + 1) \times P$

was also strong support for the idea that biodiversity protection and forest management can coexist, as expressed in the statement D. However, opinions were more divided on the role of the state in restricting forest management. A notable share of respondents agreed with the statement G, indicating that while there is concern for the rights and livelihoods of forest owners, many also support the state's authority to intervene when necessary for the sake of biodiversity protection.

3.2 Choice analysis

Before defining the final model, we estimated the optimal number of latent classes (Table 6). According to three information criteria (BIC, AIC3, CAIC), a model with five classes appeared to be the best choice. However, we observed very low class membership probabilities (some classes with membership lower than 5%) in the five-class model. Furthermore, the signs and values of the parameter estimates suggested that a four-class model would be more appropriate. Based on the class membership probabilities, respondents were classified into the following groups: 43.3%, 17.2%, 20.6%, and 18.8%.

3.2.1 Estimation of the latent class logit model

Table 7 presents the estimated model coefficients, which represent the marginal utilities of attribute changes (i.e. also changes in supply of FPS), while Fig. 5 shows the mean WTP values with 95% confidence intervals. Alongside the attribute variables, several socio-demographic and supporting variables from the survey were included. These were added progressively, and only those contributing significantly to explaining respondents' choices were retained. For interpretative clarity, the coefficients for Class 4 were normalised to zero, making all other classes interpretable in relation to this reference class.

Almost two thirds of respondents (62.1%), comprising Classes 1 and 4, have positive preferences for high-quality wood. Those in Class 1 are willing to pay €2.12 per year for every additional percentage point of wood harvested for high-quality wood products. Respondents from Class 1 (43.3%) are more likely to be retired and male. However, 17.2% of respondents (Class 2) expressed negative preferences towards high-quality wood and would expect compensation of €0.40 per year for each additional percent. These individuals are also more likely to be male than those in Class 4.

Slightly less than one fifth of respondents (18.8% – Class 4) approve of planting non-native tree species and are willing to pay €3.64 per year for each additional 1% of forest area

Table 7 Estimation results of the latent class logit model

Estimated Coefficients of the Indirect Utility Function								
Variable	**Class 1 (43.3%)**		**Class 2 (17.2%)**		**Class 3 (20.6%)**		**Class 4 (18.8%)**	
	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.
High-quality wood	0.010***	0.003	−0.015*	0.009	0.003	0.005	0.013°	0.008
Non-native tree species	0.010	0.019	−0.004	0.055	−0.062*	0.036	0.190***	0.057
Forest owner engaged in tourism (yes-1)	0.156**	0.066	−0.200	0.150	0.105	0.109	0.345*	0.199
Somebody else engaged in tourism (yes-1)	0.112	0.072	−0.312*	0.191	−0.131	0.120	0.358*	0.195
Strictly protected forest	0.008***	0.003	0.003	0.008	0.003	0.005	0.009	0.007
Activity recording (control) (yes-1)	0.333***	0.070	−0.173	0.177	0.243**	0.119	0.784***	0.191
Activity effects check (control) (yes-1)	0.356***	0.064	−0.225	0.169	0.149	0.116	0.557***	0.183
Yearly payment	−0.005***	0.001	−0.038***	0.004	−0.004***	0.002	−0.052***	0.004
ASC 1	3.476***	0.273	0.982***	0.243	0.110	0.169	3.652***	0.323
	Coefficients of the estimated latent class membership function							
Variable	Class 1		Class 2		Class 3		Class 4: reference class	
	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.		
Constant [1]	1.285***	0.411	0.626	0.479	0.662	0.565		
Retired [2]	0.594**	0.263	−0.220	0.332	0.372	0.301		
Gender [3]	−0.427*	0.235	−0.460*	0.279	0.091	0.277		
Education	0.003	0.012	0.009	0.013	−0.300**	0.129		

Estimated coefficients are significantly different from zero at a 10% (*), 5% (**), or 1% (***) significance level. Additionally, (°) denotes the coefficient estimates close to the 10% level (p-value of 0.11). McFadden Pseudo R-squared: 0.20, Log-likelihood: −6399.00, Chi-squared (p=0.000): 3279.08. [1] Alternative specific constant was coded as a non-status quo option. [2] Retired: (1) if a respondent is retired, (0) otherwise. [3] Gender: (0) for male, (1) for female

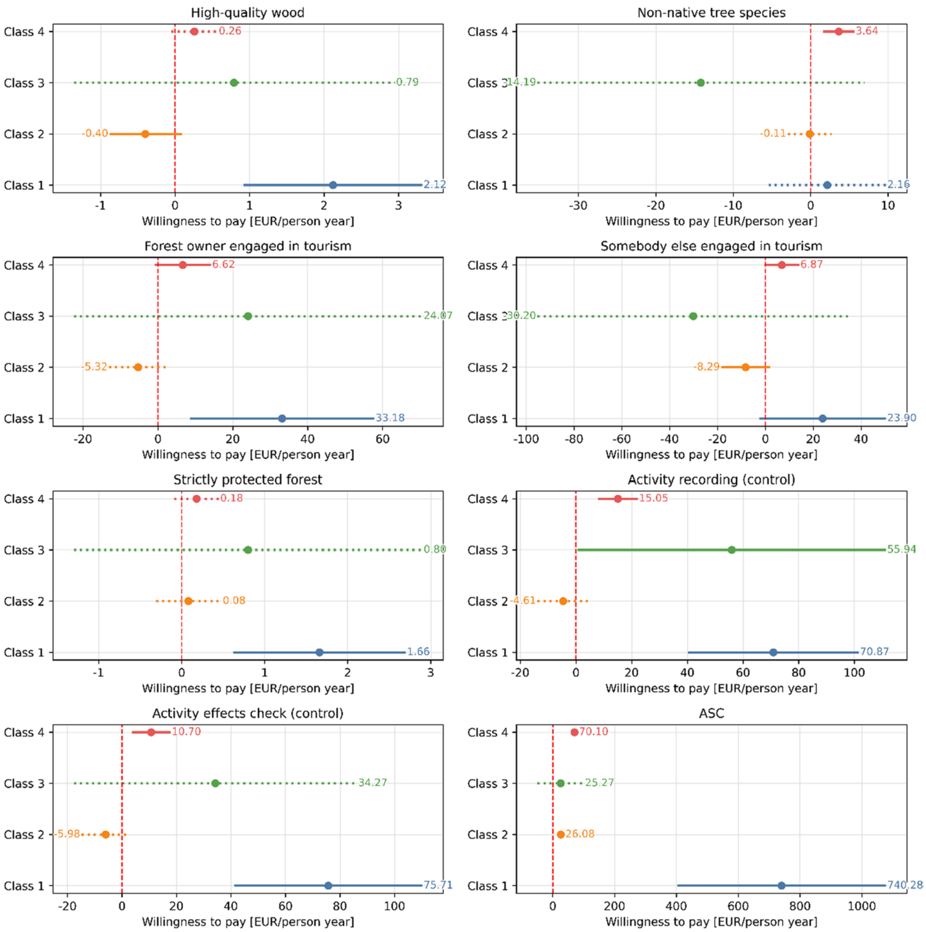


Fig. 5 Mean willingness to pay estimates (points), with 95% Delta-estimated confidence intervals (whiskers – solid line with statistically significant estimates, dashed for non-significant)

planted with them. On the other hand, 20.6% (Class 3), who are more likely to have a lower level of education, oppose this measure.

Almost two thirds of respondents (62.1% – Classes 1 and 4) support the idea that forest owners should engage in tourism activities on their land. Of these, 43.3% (Class 1) are willing to pay €33.18 per year and are more likely to be male and retired than those in Class 4 (18.8%), who are willing to pay €6.62 per year.

Meanwhile, 17.2% of respondents (Class 2) disapprove of someone else conducting tourism activities in the forest. These respondents are more likely to be male than those in Class 4 (18.8%), who show positive preferences toward this attribute and are willing to pay €6.87 per year. Also, respondents from Class 1 (43.3%), who are more likely to be male and retired, are willing to pay €23.90 € per year for that.

Among all respondents, 43.3% (Class 1) favour strict forest protection and are willing to pay €1.66 per year for each additional percent of private forests designated as strictly protected. These respondents are also more likely to be retired and male than those from Class 4.

The vast majority of respondents (79.3%), comprising Classes 1, 3, and 4, support activity recording. They would pay €70.87, €55.95, and €15.05 per year respectively for such a control system. Those in Class 1 are more likely to be male and retired, and those in Class 3 are more likely to have a lower level of education than those in Class 4.

Finally, two thirds of respondents (62.1% – Classes 1 and 4) support monitoring the effects of forest owners' activities. Of these, 43.3% (Class 1) are willing to pay €75.71 per year and are more likely to be male and retired, while the remaining 18.8% (Class 4) are willing to pay €10.70 per year for this form of control.

3.3 Public preferences for FPS and corresponding potential supply

The spatial pattern of preferences related to FPS proved to be non-random for seven out of eight preference types (Table 8). This suggests that municipalities with a higher proportion of individuals sharing similar preferences tend to cluster spatially. These results are indicated by combinations of p-values below 0.05 and positive z-scores when applying Moran's I statistic. This clustering effect was observed for both positive and negative preferences regarding an increase in high-quality wood production, strictly protected forests, and tourism managed either by forest owners or by others. It also held for positive preferences toward planting more non-native tree species, but not for negative preferences, where spatial distribution was random.

Using a derivative of the Moran's I, the incremental spatial autocorrelation, we determined a threshold distance at which the z-score peaks. This, combined with the assumption of a fixed Euclidean distance and a minimum of eight neighbouring features, allowed us to construct spatial weight matrices for delineating ADPs, which are represented as polygons on the maps in Fig. 6. The different threshold distances resulted in varying levels of spatial connectivity, ranging from 12.5% to 51.8% (see Appendix E, Table 11).

In addition to ADP, the spatial distribution of FPS-related indicator values is also visualised on maps. Higher indicator values indicate a greater potential supply of FPS, and lower values indicate a lower supply. The maps clearly show spatial heterogeneity, which can be attributed to differing ecological conditions in forested areas.

A combined presentation of ADP and the potential supply of FPS reveals interesting aspects of spatial heterogeneity, both in terms of possible factors influencing public preferences and opportunities to increase the abundance of individual FPS. These are outlined below.

Table 8 Moran's I statistic for threshold distances based on the peak z-scores for different preference types

FPS	High-quality wood		Non-native tree species		Strictly protected forests	Forest owner engaged in tourism	Someone else engaged in tourism	
Type of preference	positive	negative	positive	negative	positive	positive	positive	negative
Threshold distance [km]	68	34	50	-	76	68	50	34
Moran's I	0.03	0.03	0.03		0.01	0.03	0.03	0.03
p-value	0.00	0.05	0.00	>0.05	0.05	0.00	0.00	0.05
z-score	3.80	1.91	3.07		1.91	3.80	3.07	1.91

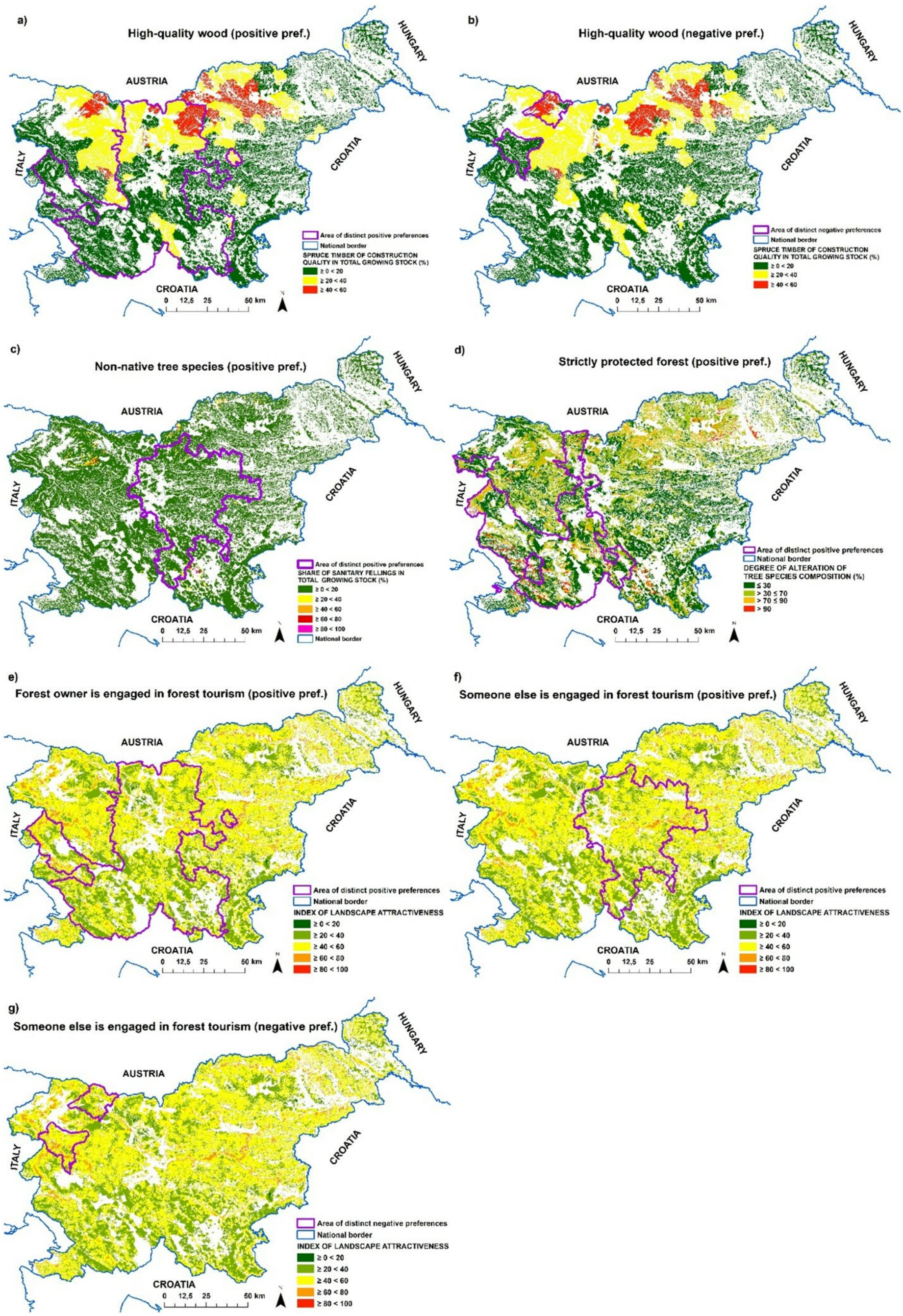


Fig. 6 Spatial distribution of FPS potential supply and ADP for FPS (demand)

3.3.1 High-quality wood

In a large ADP$^+$ (Fig. 6a) (7,171 km²), which includes the Osrednjeslovenska region, parts of the Gorenjska region with the Kamnik Alps, the Savinjska region, a large part of the Jugovzhodna region, the Primorsko-Notranjska region, and much of the Obalno-Kraška and Goriška regions, respondents expressed positive preferences for high-quality wood. A significant part of this area is heavily forested (particularly in the south) and has a strong forestry tradition, making it well suited for producing high-quality wood (Pintar et al. 2024). Additionally, a large portion of the region was affected by the 2014 ice storm (Kutnar et al. 2021), meaning that much of the forest is now in younger developmental stages and is likely to yield high-quality wood in the future. The public may also recognise that active forest management enhances not only wood quality but also provides regulating ES such as wind resistance and erosion control, as well as cultural services such as recreation and tourism, by improving safety and accessibility in forests. Tourism is also favoured in the same area, according to survey responses.

In two smaller ADP$^-$ areas (Fig. 6b) (689 km²), mostly overlapping with the Julian Alps, the Triglav National Park, and to a lesser extent the Karawanks, respondents expressed negative preferences for increasing the supply of high-quality wood through more active forest management. This aversion may stem from the perception that increased forest owner activity could lead to exploitation or overharvesting in these fragile ecosystems, characterised by steep terrain, harsh climatic conditions, and a short growing season.

The abundance of high-quality wood suitable for construction, mostly Norway spruce in Slovenia (Brus 2015; Krenn et al. 2024), is higher in ADP$^+$ area than outside of it, particularly in the north and partly in the south. This reflects where the greatest potential for supplying high-quality wood lies, especially considering that silvicultural interventions to improve future wood quality are most effective in younger stands (diameter at breast height up to 30 cm). By contrast, the potential supply within ADP$^-$ areas is lower than outside these areas (see Table 9).

3.3.2 Non-native tree species

In a relatively large ADP$^+$ (Fig. 6c) (3,536 km²), which includes the Osrednjeslovenska region, parts of Gorenjska and Savinjska (including the Kamnik Alps), Zasavje, and parts of the Jugovzhodna region, respondents expressed support for planting non-native tree species. In Slovenia, such species are primarily found in lowland areas in the east and south-west (Pintar et al. 2024). The public may recognise the role of non-native species, particularly in mixed stands, in replacing vulnerable native species affected by climate change, such as Norway spruce. Spruce, which dominates much of the growing stock in the northern part of this ADP$^+$ (and to a lesser extent the south), has shown increasing vulnerability to drought and bark beetle outbreaks (Kutnar et al. 2021; Kermavnar et al. 2023). It may be partially replaced by Douglas fir, which has so far proven more resistant to frost, drought, and bark beetles, and could help increase forest resilience (Raida 2018).

Suitable sites for planting non-native species are scattered across the southern, northwestern, and northern regions, mainly in areas where forests have been damaged by storms or ice, leaving them sparse or treeless. Planting non-native species may be a viable option to

Table 9 Testing the difference in potential supply of FPS within and outside ADP

FPS		High-quality wood (I : mean share of construction wood)		Non-native tree species (I: mean share of sanitary felling)	Strictly protected forests (I: proportion of preserved forests)	Forest owner engaged in forest tourism	Someone else engaged in forest tourism	
						(I: index of landscape attractiveness)		
Type of preference		pos.	neg.	pos.	pos.	pos.	pos.	neg.
Value of I	W	I=0.55 (med.=0.58)	I=0.42 (med.=0.36)	0.30 (med.=0.26)	0.55	42.41 (med.=41.60)	44.26 (med.=43.6)	47.34 (med.=46.40)
	O	I=0.51 (med.=0.48)	I=0.54 (med.=0.54)	0.37 (med.=0.30)	0.49	45.19 (med.=44.60)	44.15 (med.=43.3)	44.03 (med.=43.40)
Test of homogeneity of variances	W&O	$I: p = 0.47$ (F =0.53)	$I: p = 0.44$ (F =0.51)	p=0.00 (F =682.30		p=0.00 (F =5645.59)	p=0.00 (F = 2657.01)	p=0.00 (F = 700.97)
Normality test	W	$I: p < 0.2$ (d =0.13)	$I: p < 0.15$ (d =0.25)	$p < 0.01$ (d =0.20)		$p < 0.01$ (d =0.05)	$p < 0.01$ (d =0.05)	$p < 0.01$ (d =0.04)
	O	$I: p < 0.1$ (d =0.13)	$I: p < 0.15$ (d =0.08)	$p < 0.01$ (d =0.18)		$p < 0.01$ (d =0.03)	$p < 0.01$ (d =0.04)	$p < 0.01$ (d =0.05)
Mann-Whiteny U test	W/O	$I: p$ =0.00 (z =−7.37)	$I: p$ =0.04 (z =2.03)	p=0.00 (z =−20.33)		p=0.00 (z =−82.72)	p=0.00 (z =−20.03)	p=0.00 (z =45.55)
z-test for proportions	W/O				p=0.00			

I = indicator of FPS potential supply, W within ADP, O outside ADP, *med.* median increase forest resilience in these locations. However, the abundance of suitable sites within ADP$^+$ is lower than outside this area (Table 9).

3.3.3 Strictly protected forest

In an ADP$^+$ area (Fig. 6d) (4,370 km²) covering the Primorsko-Notranjska region and parts of Goriška, Obalno-Kraška, Jugovzhodna, Osrednjeslovenska, and the Gorenjska region, respondents support the strict protection of a portion of forests. This support could have several explanations. First, some forests in the northern Goriška and Gorenjska regions are remote and difficult to manage, making them good candidates for protection. Second, forests in the Goriška and Obalno-Kraška regions are less productive and therefore less economically attractive for active management. The ADP$^+$ area also overlaps with forests that were heavily damaged by the 2014 ice storm (Kutnar et al. 2021) and subsequent bark beetle infestations. As a result, many forest stands in this area now have sparse or no tree cover. This may motivate a desire to preserve the few remaining undamaged forests.

Areas with the least disturbed tree species composition, those best suited for strict protection, are scattered across Slovenia, with higher concentrations in the southern, southwestern, and western parts. Notably, the proportion of these areas is higher within ADP$^+$ than outside, indicating a higher potential supply of strictly protected forest within ADP$^+$ (Table 9).

3.3.4 Forest tourism

In a relatively large ADP$^+$ (Fig. 6f) (3,500 km²) that includes Osrednjeslovenska, parts of Gorenjska and Savinjska (with the Kamnik Alps), Zasavje, and part of the Jugovzhodna region, the public supports the idea of third parties, such as tourism companies, conducting tourism activities in private forests. This may reflect the underdevelopment of tourism infrastructure in these regions (aside from the capital and Alpine areas). The public might therefore support external providers who can invest in infrastructure and have the expertise to organise tourism.

A slightly larger ADP$^+$ (Fig. 6e) (7,172 km²), covering much of the same area and extending into the entire Primorsko-Notranjska region, parts of Obalno-Kraška, Goriška, and Gorenjska (Karawanks), as well as most of Jugovzhodna, shows public support for forest owners conducting tourism themselves. This suggests that the public sees an opportunity for local development, especially given the relatively high number of private forests in these regions. Forest tourism is already present in the Karawanks and Kamnik Alps, though to a lesser extent than in the Julian Alps, and is seen as having room for growth. Moreover, the public appears to support forest tourism that remains under local control and benefits local stakeholders.

In contrast, two smaller ADP$^-$ areas (Fig. 6g) (689 km²), mostly overlapping with the Julian Alps and Triglav National Park, and to a lesser extent with the Karawanks, show negative public attitudes towards third-party forest tourism. Tourism is already abundant in this area (Slovenian Tourism Board 2024), but it is strictly regulated as part of a protected area. The public may perceive additional tourism as a potential threat to the already fragile forest ecosystems. Furthermore, the stringent conservation regime may make these areas less attractive for commercial tourism development. Public opposition may also stem from the desire to protect local interests, traditional forest use, and ethical considerations.

Areas with high scores on the landscape attractiveness index are scattered across the country. A relatively large area with lower index values lies in southern and south-western Slovenia. When comparing spatial patterns, we find that potential supply for forest tourism by external providers is higher inside ADP^{+} than outside. Conversely, the potential supply for the same service is higher inside ADP^{-} than outside, and the potential supply for owner-led tourism is lower inside ADP^{+} than outside (Table 9).

Differences in the potential supply of FPS between inside and outside ADP are statistically significant for all seven preference types where clustering is significant. Table 9 presents not only the indicator values and test statistics (with *p*-values) but also test results for the homogeneity of variances and the normality of distributions, which determined the appropriate statistical test for each case.

When comparing the potential supply of FPS within and outside the ADP, several outcomes can be observed. In three cases, a higher potential supply within the ADP aligns with positive public preferences in the same area. These include high-quality wood, strictly protected forests, and forest tourism involving a non-owner (see also Fig. 6: a, d, f). These are situations in which both allocative efficiency and resource use efficiency are achieved. Another case of alignment occurs, though in the opposite context: in one ADP, there is a lower potential supply of FPS combined with negative public preferences – this also concerns high-quality wood (Fig. 6: b). In this case, the limited supply is consistent with low demand, suggesting that no additional support measures are required. The remaining three cases show a mismatch between potential supply and preferences. In two of them – non-native tree species and forest tourism where forest owners are engaged (Fig. 6: c, e) – preferences within the ADP are positive, but the potential supply is lower than outside the ADP. These represent areas where public support exists, but current ecological conditions may not enable increased provision without targeted investment or restoration. In the final case – forest tourism involving a non-owner (Fig. 6: g) – preferences are negative, but the potential supply is higher than outside the ADP. This suggests that public sentiment may act as a limiting factor, even where ecological conditions are favourable. These outcomes are summarised in Table 10, where ADP areas (a–g) are categorised into four quadrants. The first quadrant includes positive preferences and high potential supply, indicating the presence of both efficiency elements (dark green). The second and third quadrants represent a mismatch – either positive preferences with low supply or negative preferences with high supply – both indicating the absence of one efficiency element (green). The final quadrant

Table 10 A cross-sectional demonstration of the potential for increased supply of FPS and corresponding preferences within ADP in terms of allocative and resource use efficiency

		Preferences for more FPS within ADP		Resource use efficiency
		Negative	Positive	
Potential for increased supply of FPS within ADP (compared to outside)	Higher	Someone else is engaged tourism (area g)	High-quality wood (area a) Strictly protected forests (area d) Someone else is engaged in tourism (area f)	+
	Lower	High-quality wood (area b)	Non-native tree species (area c) Forest owner is engaged in tourism (area e)	-
Allocative efficiency		-	+	

reflects areas where negative preferences align with low supply, meaning both efficiency elements are lacking (light green).

4 Disussion

4.1 First glance of peoples' position on directions of EU Forest-related policy

To establish a foundation for understanding how the public perceives four key aspects of EU forest-related policies and their relation to the four FPS explored in our research, we asked respondents to indicate their level of agreement with four sets of statements. The results show that respondents emphasise the importance of high-quality wood for durable, value-added products and as a sustainable, low-carbon substitute in construction. They support enhancing forest resilience to climate change by planting a greater diversity of tree species – including non-native ones – albeit cautiously. Forest tourism is widely recognised as a valuable source of revenue that should involve forest owners, even though views are more divided concerning its potential impact on forest ecosystems and access for local recreation. Additionally, there is strong support for biodiversity conservation through habitat protection and careful use of ecologically valuable trees, although opinions vary regarding the current extent of forest protection and the appropriateness of government restrictions on forest management.

4.2 Innovative aspects of the presented pilot approach

The central part of this paper presents our efforts to develop and test a policy planning approach that supports FPS. This approach is contextualised within key forest-related EU policies and builds on an integrated assessment of both the demand and potential supply of FPS. By aligning research insights with the strategic objectives of relevant EU policies, systematically assessing the demand and potential supply of selected forest ecosystem services, and situating this assessment within a policy-efficiency framework, our approach provides an innovative contribution by integrating these three dimensions into a single conceptual approach. We also aim to broaden the scope of ES research beyond simple comparisons of supply and demand using statistical or modelling tools. The outcomes themselves are not directly transferable to the socio-ecological conditions of other countries; however, the approach we designed and tested is. If the precondition of empirical data availability is met, countries yet to complete their national BE strategies—11 EU countries have done so (EC 2025)—might apply the concept of ADPs alongside the forests' capacity to provide ES, thereby identifying areas where policy interventions would efficiently support the implementation of forest-based BE.

4.3 Forest-related policy implications

The analysed FPS cases span the entire spectrum of combinations between demand and potential supply, covering all possible pairings of the two policy efficiency elements. This creates a broad set of opportunities for implementing forest-related EU policy goals. The cases of high-quality wood, strictly protected forests, and forest tourism involving a non-owner (ADP-a, -d, -f) are examples where both public preferences and ecological potential are high within ADP, compared to outside. In these situations, expanding the supply of FPS would directly benefit local communities and is feasible from an ecological perspective. Supporting these products and services would therefore be efficient in terms of both allocative and resource use criteria. Higher potential supply within ADP means that resources can be used efficiently to support FPS. This includes measures such as tending young forest stands to improve high-quality wood output, placing ecologically suitable areas under stricter protection, and training guides to provide tourism services and interpret the natural landscape. These actions would align well with the preferences of local communities and therefore meet the condition of allocative efficiency. When generalising the proportion of respondents with positive preferences to the broader population, we can better understand the level of public support: 72% of people in ADP-a support an increase in high-quality wood, 61% in ADP-d support more strict forest reserves, and 35% in ADP-f favour forest tourism involving non-owners. These results suggest that ADP-a, -d, and -f should be prioritised in implementing the strategic objectives of relevant EU policies, including: (1) the promotion of wooden construction to reduce emissions from the building sector while creating green jobs and healthier living environments (EU Forest Strategy (2021), EU BE Strategy (2018)); (2) the EU Biodiversity Strategy's target to place at least 30% of the EU's land under effective conservation, with 10% under strict legal protection; and (3) the development of sustainable forest tourism that supports human health without degrading the forest ecosystem (EU Forest Strategy (2021)).

By contrast, the case of high-quality wood in ADP-b demonstrates low public support and a lower potential supply than outside the ADP. Efforts to expand FPS in such areas would fail to meet either efficiency criterion – there is neither social demand nor ecological justification – and should therefore not be prioritised for policy intervention.

Three other cases fall somewhere in between. ADP-g, where forest tourism is led by a non-owner, shows relatively high potential supply – in terms of landscape attractiveness – but is not supported by public preferences. This violates the condition of allocative efficiency, and thus it would not make sense to invest in this type of tourism in this area. Similarly, ADP-c and ADP-e – related to planting non-native tree species and tourism led by forest owners, respectively – are both associated with positive public preferences but lower potential supply than outside the ADP. Even if the public supports such measures, increasing supply here would not be efficient from a resource use perspective. An aspect not considered empirically but potentially of interest for future research, is the overlap of ADP-f and ADP-e, where preferences for both formats of forest tourism are positive. This may indicate an additional area of interest—a cluster of municipalities where respondents share positive preferences for both forest tourism-related options—where an assessment of FPS availability would show if it's aligned with societal needs.

From these cases, we can draw two key conclusions. First, public preferences regarding the provision of FPS are highly heterogeneous. This was already evident in the results of the discrete choice experiment, where four distinct latent classes of respondents were needed to model variation in preferences, and these patterns were reflected in the different ADP. Other studies have also reported similar findings, linking preference heterogeneity to sociodemographic variables (Aguilar et al. 2018; Castillo-Eguskitza et al. 2019; Tavárez and Elbakidze 2019; Unterberger and Olschewski 2021; Sacher et al. 2022). Our study confirms this connection. For instance, respondents who are more likely to be male and retired support increased provision of high-quality wood, stricter conservation, and the involvement of private forest owners in tourism. At the same time, male respondents are less supportive of engaging non-owners in forest tourism, and those with lower levels of education tend to oppose planting non-native species to restore damaged forests. These findings support our first hypothesis: Public preferences are heterogeneous and depend on socio-demographic characteristics.

Second, preferences for FPS do not always align with the potential supply available to meet them. Spatial clustering of respondents with similar preferences allowed us to identify ADP, which serve as a basis for comparing demand with supply. Using a four-quadrant method, we illustrated a range of cases representing different combinations of preference and potential supply. These enable managers to determine where to take action and where to refrain. In doing so, we confirm our second hypothesis: The potential supply of FPS does not fully align with public preferences. This aligns with findings from previous studies exploring relationships between supply and demand for ES. For example, Wang et al. (2021) examined trade-offs and synergies among ES to inform rural landscape management. Lin et al. (2024) proposed ecological zoning based on ES supply-demand ratios and established four distinct ecological management bundles (zones) which relate to different combinations of supply and demand. Differently from our study, the bundles were created by considering three ES simultaneously and not for each ES individual, which might affect the reliability of such outcomes. Yu et al. (2023) developed a typology of matched and mismatched areas similar to our ADP classification, but does not progress towards zoning for targeted management, which essentially falls short to provide a clear context for spatially focused policy interventions. Similarly, Wang et al. (2019), also did not implement zoning but rather used interactions and trade-offs among ES to demonstrate spatial co-occurrence patterns as bundles of various ES. They relate this to land use, which is linked to policy measures of land management as a tool for supporting ES supply.

One critical element for successful policy implementation is control (monitoring) – that is, ensuring that the intended actions are properly carried out. Control mechanisms help track outcomes, identify problems early, and ensure accountability in the use of public resources (Viaggi 2018; Šumrada et al. 2022). Our survey revealed broad public support for both types of monitoring. Nearly 80% support the idea of forest owners recording their activities, and about two thirds support monitoring the effects of those activities. This indicates that while the public largely trusts forest owners, it also sees the importance of independent oversight.

The above listed outcomes can support several national forest policies related efforts. Having information on the potential supply and demand nexus for FPS may be useful for drafting a national BE strategy which Slovenia still lacks. Such information would also be valuable for updating and complementing the currently outdated National Forest Programme (Government of Slovenia 2007), which could integrate those aspects as strategic goals to be defined in detail by the next 10-year Operational Programme for implementation of the national forest program (MAFF 2022). The connection between such a strategic vision and regional forest management is possible through forest management plans provided by the Slovenia Forest Service which establish preconditions for financial incentives for landowners to implement management measures in their forests.

4.4 Limitations of the study and future research needs

This study offers a detailed look at how forests can support key EU Green Deal objectives by examining public preferences for selected FPS and comparing them to potential supply, while evaluating these findings through the lens of policy efficiency. However, it has several limitations. First, only a limited number of FPS were included. Forests provide many more services – the Slovenian Forest Act (Government of Slovenia 1993) defines 17 forest functions – and future research should explore a broader set. Second, we did not include a temporal dimension. Several recent studies (Wei et al. 2023; Chen et al. 2024; Zhang et al. 2024, 2025; de Knegt et al. 2025; Gao et al. 2025b) have incorporated time dynamics, which can shed light on whether supply and demand are increasing or declining and why. This kind of information could help identify whether changes are due to environmental conditions, management practices, or policy interventions. In our case, such an analysis was not possible due to the lack of historical data. Forest-related stated preference studies are rare in Slovenia, and no national-level survey has been repeated over time with the same FPS focus. Finally, our spatial resolution was limited by the data available. Respondents' place of residence was recorded at the municipal level, which restricted the precision of the ADP we could identify. More detailed spatial data could allow the delineation of smaller, more actionable ADP, giving policymakers clearer guidance on where to prioritise support for different FPS. Future work – especially efforts to locate FPS hotspots – could help address this gap.

5 Conclusions and outlook

In this paper, we present a novel approach for identifying areas where implementing forest-related policy goals would meet two key efficiency criteria: allocative efficiency and resource use efficiency. The method is based on an integrated assessment of public preferences for forest ES-based products and services (FPS), and the potential of ecosystems to supply them. This can inform management decisions on where, and for which FPS, supply should be mobilised to achieve policy goals.

The approach was tested at the national level and could contribute to the revision of the EU BE Strategy, as it provides spatially explicit insights into where forests have a higher potential to deliver FPS, supporting the prioritisation of management interventions. Since the method also includes public attitudes towards FPS, it should be discussed among a broader audience. Decision-makers and businesses are both key actors in the implementation of the BE – the former must create an enabling policy environment, while the latter can act by providing FPS in various ways. These include wood-processing companies producing construction timber, forestry companies replanting damaged areas with more resilient non-native tree species, and tourism or recreation businesses – including private forest owners – offering outdoor activities in forest settings.

In addition, the study explored the issue of designating forest areas for strict protection, which is relevant in the context of the EU Nature Restoration Regulation. The ongoing development of restoration plans should be supported not only by data on ecological priority areas, but also by public attitudes toward nature conservation measures.

While our study presents a pilot test of the concept, and further refinement and validation are needed, it represents a meaningful step forward in managing forest resources to support the forest-based BE.

Appendix A. Description of attributes used in the DCE

"High-quality wood"

Currently, only about 50% of the wood harvested in Slovenia's private forests is processed into sawn wood suitable for high-quality products such as construction timber, windows and doors, and interior furnishings. This share could be increased through more intensive forest tending by private owners, making a greater quantity of high-quality Slovenian wood products available for use.

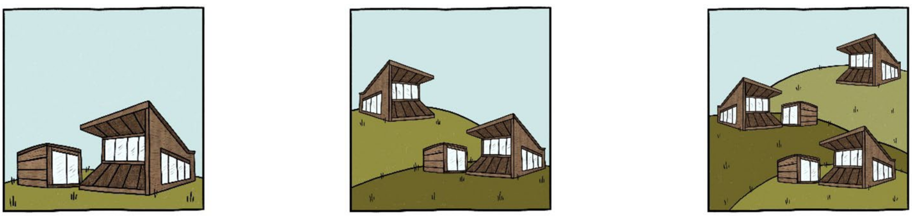
The figure below (Fig. 7) illustrates the shares of high-quality wood (a, b, c).

"Non-native tree species" refers to the proportion of newly planted non-native species within a forest property. Their current presence in Slovenian forests is minimal – under 1%, according to the SFS (SFS 2022). With targeted financial support from an earmarked fund, this share could increase to 2–3% of the national forest area, enhancing resilience to climate-related disturbances.

The figure below (Fig. 8) illustrates the areas covered by non-native tree species (a, b, c)

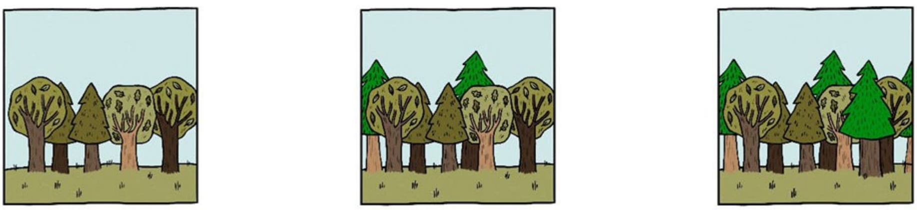
We consider two options for implementing *"forest tourism"*. The first is that the forest owner independently offers tourism activities on their land – for example, guided walks along thematic trails, meditation, or glamping – and receives financial compensation from an earmarked fund. This support may also help maintain infrastructure or finance educational programmes. Alternatively, the forest owner may authorise another party (e.g. a tourism company) to conduct activities. In this case, the earmarked fund can be used to train the company's staff and/or to compensate the forest owner for the use of their land.

The figure below (Fig. 9) illustrates possible forest tourism options (a, b, c)



(a) 50% of high-quality wood (b) 60% of high-quality wood (c) 70% of high-quality wood

Fig. 7 Different shares of high-quality wood used in the DCE

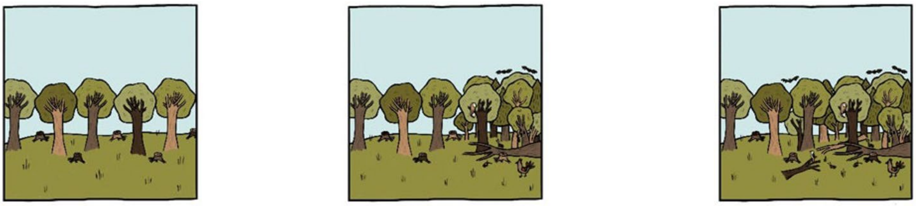


(a) 0.4% (b) 2% (c) 3%

Fig. 8 Different shares of forest area covered by non-native tree species used in the DCE

(a) Unregulated (b) Forest owner is engaged in tourism (c) Somebody else is engaged in tourism

Fig. 9 Different options of forest tourism implementation used in the DCE



(a) 0.3% (b) 5% (c) 20%

Fig. 10 Different extents of strictly protected forest used in the DCE

The proportion of *"strictly protected forests"* refers to the share of forest land designated for natural development, with the aim of enhancing biodiversity. Currently, less than 1% of Slovenia's privately owned forests are under strict protection as forest reserves. With increased funding from an earmarked fund, more areas could be protected, and forest owners compensated for lost income due to management restrictions.

The figure below (Fig. 10) illustrates the shares of strictly protected forests (a, b, c)

"Control" (monitoring) refers to methods used to verify that forest management activities, supported by an earmarked fund, are implemented as agreed. The first option – activity recording – requires forest owners to document their actions and report to the forestry service. The second – activity effects check – involves periodic visits from an expert who evaluates the impact of those activities onsite. These may include tending, planting non-native species, tourism services, and strict protection efforts.

The figure below (Fig. 11) illustrates the possibilities for controlling the activities undertaken (a, b, c)

(a) no control system (b) activity recording (c) activity effects check

Fig. 11 Different options for controlling forest management activities used in the DCE Appendix B. Illustration of a Representative Choice Set Used in the DCE

Appendix B. Illustration of a Representative Choice Set Used in the DCE

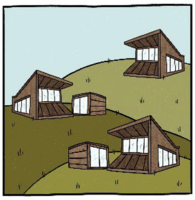
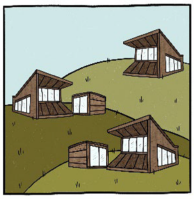
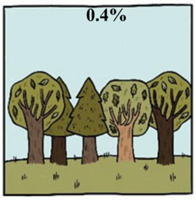
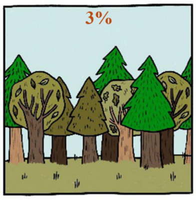
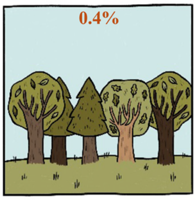
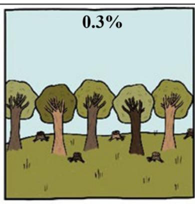
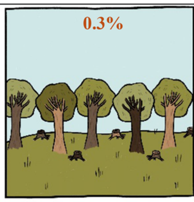
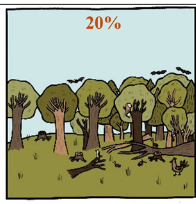
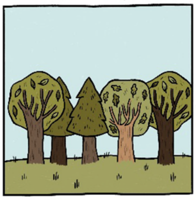
	Without additional activities	With additional activities	
	Status quo	Option A	Option B
HIGH-QUALITY WOOD	50% 	70% 	70% 
NON-NATIVE TREE SPECIES	0.4% 	3% 	0.4% 
FOREST TOURISM	Unregulated 	Somebody else engaged in tourism 	Forest owner engaged in tourism 
STRICTLY PROTECTED FOREST	0.3% 	0.3% 	20% 
CONTROL	No control system 	Activity effects check 	Activity recording 
YEARLY PAYMENT	0 €	20 €	60 €
CHOICE			

Fig. 12 A representative choice set used in the DCE

Appendix C. Distribution of Municipalities and Statistical Regions in Slovenia

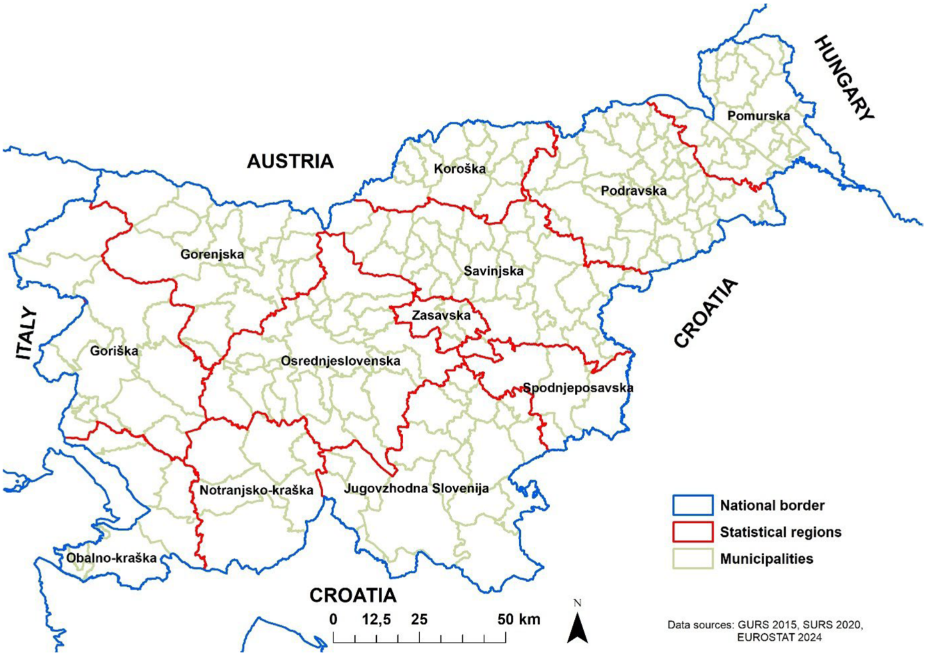


Fig. 13 Distribution of municipalities, statistical regions and the national border of Slovenia (SMARS 2015, 2022; SURS 2023; EUROSTAT 2024)

Appendix D. Biophysical Indicators for Assessing Potential Supply of FPS, Data Used for Their Estimation, and the Description of Measures to Support Potential Supply (Referring to Table 4)

High-quality wood that can be used for construction and other wooden products was assessed by examining the share of wood from Norway spruce, the most common conifer species in Slovenia, using data from the national forest inventory, which is conducted continuously across the country (Skudnik et al. 2024). Out of a total of 2,194 inventory plots (measured between 2022 and 2024), 424 plots are located in areas of distinct positive preferences and contain spruce, while 48 plots are located in areas of distinct negative preferences and also contain spruce. When focusing only on relatively young stands, where tending has the greatest potential to improve wood quality (i.e. trees with diameter at breast height of 10–30 cm), the number of relevant plots drops to

104 (with 147 outside the ADP) and 10 (with 241 outside the ADP), respectively. The growing stock of spruce on these plots, together with an estimate of the average share of construction-quality wood, was used to calculate the corresponding percentage of high-quality wood for within and outside ADP.

Non-native tree species can be most efficiently introduced in forest areas with sparse or no tree cover, typically resulting from damage by abiotic or biotic agents. Such areas require timely replanting, preferably with species that are more resilient to future disturbances. The potential for planting was assessed using the SFS database (SFS 2024) by identifying areas where sanitary felling exceeded 20% of the total growing stock. A weighted mean of the share of sanitary felling relative to total growing stock was calculated, using forest stand area as the weighting factor. This calculation was performed separately for areas within and outside ADP.

Forest tourism depends not only on the availability of people with appropriate skills and infrastructure, but also on the natural attractiveness of the landscape. To quantify this, an index of landscape attractiveness was developed as an indicator of the environment's potential for outdoor recreation and tourism. The index was based on and extended from earlier work on the recreation potential index (Paracchini et al. 2014). It consists of five components: (1) level of naturalness, estimated using hemeroby (Koch, Kirchmeier 1999); (2) presence of water bodies, incorporating a distance-decay effect; (3) heterogeneity of forest types; (4) terrain ruggedness index (Riley et al. 1999); and (5) the number of mountain peaks within a fixed area. Each component was mapped in a GIS environment as a raster layer (100 × 100 m), standardised to a 0–100 scale, summed, and then re-standardised to produce a final index value between 0 and 100. Lower index values indicate less attractive landscapes, while higher values reflect more attractive ones.

Designating forest stands with a relatively undisturbed tree species composition for stricter protection can contribute to biodiversity conservation. The extent of these stands was calculated by measuring the degree of deviation from natural tree composition for a given forest site type, using SFS data (SFS 2024). We included only areas with minimal alteration – defined as those where uncommon tree species comprise up to 30% of the growing stock – both within and outside ADP.

For all four FPS, indicator values within and outside ADP were statistically compared using either a parametric z-test or a non-parametric Mann–Whitney U test. The choice of test was based on the results of the Kolmogorov–Smirnov normality test (or the Lilliefors test for smaller sample sizes), and Levene's test for homogeneity of variances. These tests allowed us to determine whether the potential supply of a particular FPS was significantly higher or lower within ADP compared to outside, or whether no significant difference was observed. This, in turn, indicated whether an intervention to support the supply of that FPS would be justified or not.

Appendix E. Percentages of Spatial Connectivity and the Number of Neighbouring Features in Relation to the Threshold Distance

Table 11 Percentages of spatial connectivity and the number of neighbouring features in relation to the threshold distance

Threshold distance [km]	Spatial connectivity [%]	Average number of neighbouring features	Maximum number of neighbouring features
30	12.48	26.46	49
40	19.98	42.35	66
50	27.95	59.25	88
60	36.04	76.40	110
70	43.97	93.23	134
80	51.85	109.92	152

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Authors' contributions Conceptualization: Kaja Plevnik, Anže Japelj; Methodology: Kaja Plevnik, Anže Japelj; Validation: Kaja Plevnik, Anže Japelj; Formal analysis: Kaja Plevnik, Anže Japelj; Investigation: Kaja Plevnik, Anže Japelj; Resources: Kaja Plevnik, Anže Japelj, Anže Martin Pintar; Data curation: Kaja Plevnik, Anže Japelj; Writing—original draft preparation: Kaja Plevnik, Anže Japelj; Writing—review and editing: Kaja Plevnik, Anže Japelj, Anže Martin Pintar; Visualization: Kaja Plevnik, Anže Martin Pintar; Supervision: Anže Japelj; Project Administration: Kaja Plevnik, Anže Japelj; Funding acquisition: Anže Japelj.

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Data availability Data will be made available upon reasonable request.

Declarations

Competing interests There are no competing interests related to this research.

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