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Biodiversity-oriented forest management aligns with societal preferences across Europe

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Abstract: Forests across Europe are undergoing rapid transformation as biodiversity loss and climate change reshape priorities for forest management. Strategies that promote biodiverse and structurally complex forests are increasingly advocated to enhance ecological resilience, yet they are often assumed to conflict with societal preferences, potentially limiting public support for conservation and restoration. We examined whether forest characteristics associated with biodiversity conservation and climate adaptation are consistently valued by society across Europe. We combined a visual discrete choice experiment involving 11,622 respondents from twelve European countries with a travel cost model to evaluate whether stated societal preferences were reflected in observed recreational behaviour. We then integrated harmonized preference estimates with continental forest inventory and remote-sensing data to map the spatial distribution of societal values associated with forest ecosystem condition. Across all countries, respondents consistently preferred forests characterized by taller canopies, greater tree-species richness, heterogeneous age structures, and more deadwood. These preferences closely aligned with observed visitation behaviour despite substantial differences in geography, accessibility, and recreational traditions. Spatial analyses further showed that forests with greater structural complexity consistently exhibited higher societal value. Our findings demonstrate that biodiversity-oriented forest management and societal values largely converge across Europe, suggesting that many interventions promoting ecological resilience can simultaneously strengthen public support for forest conservation and restoration, providing a stronger foundation for adaptive, multifunctional forest governance under global environmental change.

Keywords: biodiversity conservation, forest management, structural complexity, forest recreation, ecosystem services, discrete choice experiment, travel cost method

JEL codes: Q57, Q23, Q26, Q51

1 Introduction

Forests across Europe are undergoing rapid ecological transformation under accelerating global environmental change. Climate warming, intensifying drought, bark beetle outbreaks, wildfires, and wind disturbances are reshaping forest composition, structure, and functioning at unprecedented rates across large spatial scales (Seidl et al., 2017; Senf and Seidl, 2021; Schuldt et al., 2020; Hartmann et al., 2025; McDowell et al., 2020). This challenges the capacity of forest ecosystems to sustain biodiversity, ecosystem functioning, and the benefits they provide to society (Watson et al., 2018). In response, forest conservation stakeholders have increasingly promoted management and restoration strategies for structurally diverse and species-rich forests to enhance resilience to climate-driven disturbances while simultaneously supporting biodiversity conservation and ecosystem multifunctionality (Messier et al., 2022; Forrester and Bauhus, 2016; Bauhus et al., 2017). Management strategies such as longer rotation lengths that promote drought resilience (Bussotti et al., 2015), mixed-species stands, uneven-aged structures, and greater retention of deadwood have consequently become central components of climate-adaptive forest landscapes across Europe (Langenbacher et al., 2026). Implementing these ecological transitions, however, is dependent on both ecological effectiveness and societal acceptance. Forests are multifunctional socio–ecological systems that must concurrently support biodiversity and natural ecosystem processes while meeting diverse societal needs, including timber production and opportunities for experiencing nature for health, recreation, and cultural purposes (Kremen and Merenlender, 2018). Decisions about how forest ecosystems are managed therefore involve balancing ecological and societal priorities, and public support is essential to the long-term success and legitimacy of conservation and restoration initiatives (Farwig et al., 2025). Yet biodiversity-oriented management is often assumed to involve trade-offs with public preferences, based on concerns that forests managed to promote ecological priorities may be perceived as less attractive, accessible, or suitable for meeting diverse societal needs (Ellis et al., 2019). Such assumptions still influence forest management strategies, despite the lack of empirical evidence on the alignment of ecological resilience with societal preferences. Emerging evidence suggests that the opposite may be true. Many structural characteristics associated with high ecosystem quality and ecological resilience, such as greater tree-species richness, taller canopies, heterogeneous age structures, and the presence of deadwood (McElhinny et al., 2005; Ehbrecht et al., 2017; Seidel et al., 2019), are also associated with stronger positive perceptions and experiences of forests (Edwards et al., 2012; Giergiczny et al., 2015; Filyushkina et al., 2017; Sacher et al., 2022). For example, Giergiczny et al. (2015) found that respondents were willing to travel farther to visit forests with greater tree-species richness and more structurally diverse stands than species-poor, structurally simplified forests. However, existing evidence remains overwhelmingly derived from local or regional case studies, making it unclear whether these relationships hold across broader ecological, geographical, and cultural contexts. More fundamentally, most studies examine either ecological indicators or human responses in isolation, leaving unresolved whether biodiversity-oriented forest management consistently aligns with societal preferences at the scales relevant for policy.

Understanding this alignment requires distinguishing between what people say they prefer and how they actually behave. Environmental and conservation psychology have long recognised that values, preferences, and attitudes do not necessarily translate into observed behaviour, as behaviour is additionally shaped by contextual factors such as opportunity structures, personal beliefs, and practical constraints (Ajzen, 1991). For example, an individual may express a strong preference for biodiverse forests yet visit them infrequently if they are difficult to access or if competing recreational opportunities are more convenient. As such, understanding human preferences alone cannot establish whether the forest ecosystems that people prefer also shape their actual interactions with these ecosystems, for example, through the frequency of visits to these forests, the duration of each visit, and the activities conducted there. As such, an assessment of this relationship requires integrating measures of societal preferences with independent evidence of behaviour, for the same set of forest ecosystem conditions. This interdiscplinary assessement remain exceptionally rare, particularly across large socio-ecological landscapes.

This knowledge gap limits the ability of stakeholders, from forest managers to policymakers, to incorporate societal preferences into climate adaptation and management planning. While harmonized forest inventories and remote sensing now provide increasingly detailed assessments of forest ecosystem condition across Europe, social information remains comparatively fragmented (Scheidel and Gingrich, 2020; Rekola et al., 2025). Europe-scale assessments of cultural ecosystem services typically represent forests as homogeneous land-cover classes, overlooking substantial variation in forest quality and composition (Vallecillo et al., 2019), whereas valuation studies remain largely confined to local case studies that cannot be readily transferred across regions. As a result, there is currently no harmonized study that simultaneously evaluates whether the ecological characteristics promoted for biodiversity conservation are also those consistently preferred by society, reflected in observed behaviour, and spatially distributed across European forests.

Here, we address this gap by integrating preference and behavioural considerations with environmental valuation and continental-scale ecological data to examine the alignment between biodiversity-oriented forest management and societal preferences across Europe. We first estimate societal preferences for key dimensions of forest structural complexity using a visual discrete choice experiment involving 11,622 respondents from twelve European countries. We then evaluate whether these experimentally-derived preferences are reflected in observed behavior using a travel cost model. This provides an independent behavioral assessment of societal preference patterns. Finally, we integrate harmonized preference estimates with European forest inventories and remote-sensing datasets to map the spatial distribution of societal preferences associated with forest ecosystem condition. By linking societal preferences and observed behavior with ecological indicators within a common analytical framework, our study provides evidence on whether biodiversity-oriented forest management and societal preferences converge across Europe, and offers a foundation that integrates ecological resilience and public priorities in forest governance under global environmental change.

2 Methods

2.1 Study Design

Our study comprised three sequential components (Figure 1). First, we estimated societal preferences for key components of forest structural complexity using a visual discrete choice experiment (DCE) conducted in twelve European countries. The DCE quantified the trade-offs respondents were willing to make among alternative forest characteristics and travel distances under controlled experimental conditions. This approach allowed us to evaluate a broad gradient of forest ecosystem conditions, ranging from intensively managed, plantation-like stands to more naturally occurring, structurally complex forests. Such variation is challenging to observe under natural conditions because forest characteristics such as canopy height, species composition, and age structure tend to co-vary, making it difficult to isolate their individual contributions to human preferences.

Second, we assessed whether experimentally derived societal preferences were reflected in observed behaviour using the travel cost method (TCM). This provided an independent test of whether forest characteristics preferred under controlled experimental conditions were also associated with actual forest visitation.

Finally, we integrated harmonized preference estimates with European forest inventories and remote-sensing datasets to map the spatial distribution of societal preferences associated with forest ecosystem condition. Together, these three components provided complementary evidence for assessing whether ecological characteristics promoted for biodiversity conservation and climate adaptation are also those consistently preferred by the public.

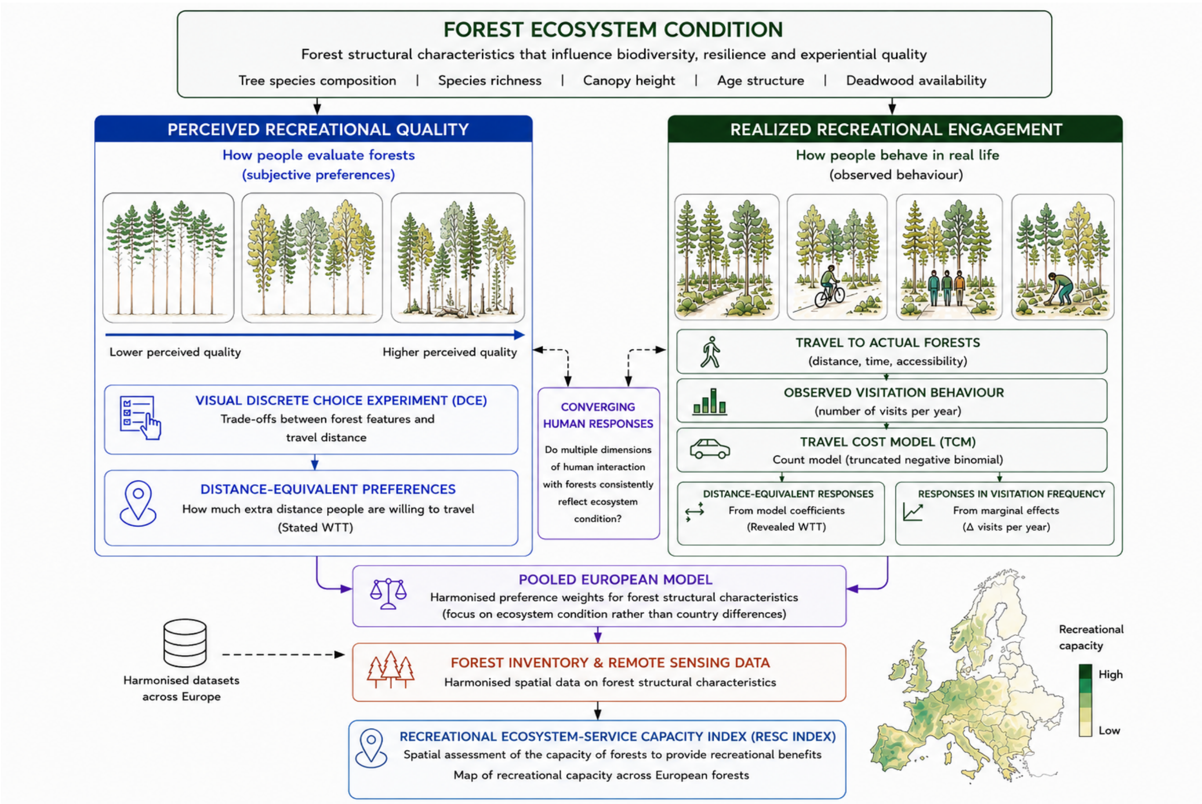

Figure 1: **Analytical framework of the study.** The framework links forest ecosystem condition to experimentally elicited societal preferences, observed forest-visitation behaviour, and spatial indicators of Forest Recreational Potential (FRP) across Europe.

2.2 Survey Design

We obtained survey data from nationally representative samples of approximately 800–1,000 respondents in each of twelve European countries: Austria, Belarus, Bulgaria, Czechia, Denmark, France, Germany, Poland, Romania, Scotland, Slovakia, and Switzerland. Surveys were conducted in 2017, except in Belarus, Bulgaria, and Romania, where data were collected in 2022. Questionnaires were translated into the respective national languages by native speakers to ensure conceptual equivalence across countries.

Only respondents who had visited a forest at least once during the previous 12 months were eligible to participate. The final dataset comprised 11,622 respondents and included socio-demographic information together with detailed responses about their most recently visited forest, including visitation frequency, travel distance, and forest characteristics.

2.3 Estimating societal preferences for forest ecosystem condition

Societal preferences were quantified using a visual discrete choice experiment (DCE), an established method for estimating the relative importance individuals assign to alternative ecosystem characteristics (Carson and Czajkowski, 2014). Forest ecosystem condition was represented by five characteristics commonly associated with biodiversity conservation and structurally diverse forest management: forest type, tree-species richness, canopy height, forest age structure, and deadwood availability. Travel distance was included as a sixth attribute, allowing preferences for changes in forest condition to be expressed in distance-equivalent terms. The attributes, their experimental levels, and representative examples of the visual stimuli presented to respondents are shown in Figure 2.

Forest conditions were represented using a library of 675 computer-generated illustrations. The library combined 15 tree-species compositions—all possible one- to four-species combinations of beech, oak, pine, and spruce—with five canopy height/age-structure combinations (8-, 18-, and 24-m single-aged stands, and 24-m two-aged and uneven-aged stands). These were further combined with nine variants obtained by crossing three levels of deadwood availability with three levels of understory development, yielding $15 \times 5 \times 9 = 675$ unique illustrations. Together, these illustrations spanned a broad gradient of forest composition and structural complexity, from simple, plantation-like stands to structurally heterogeneous, close-to-nature forests. The experimental design sampled from this image library to construct the choice alternatives.

Prior to the DCE, respondents characterized their most recently visited forest using the same five forest characteristics. This forest served as the reference alternative in all subsequent choice tasks, thereby anchoring hypothetical choices in respondents' own forest-visiting experience.

Each respondent completed twelve choice tasks generated using a Bayesian D-efficient experimental design (Rose and Bliemer, 2009). Each task comprised the reference alternative and two hypothetical forest alternatives that varied in forest characteristics and travel distance. Travel distance was pivoted around the distance to the respondent's most recently visited forest. The resulting preference estimates were expressed in willingness-to-travel (WTT) space, representing the additional distance respondents were willing to travel for changes in individual forest characteristics. An example choice card is provided in the Supplementary Materials.

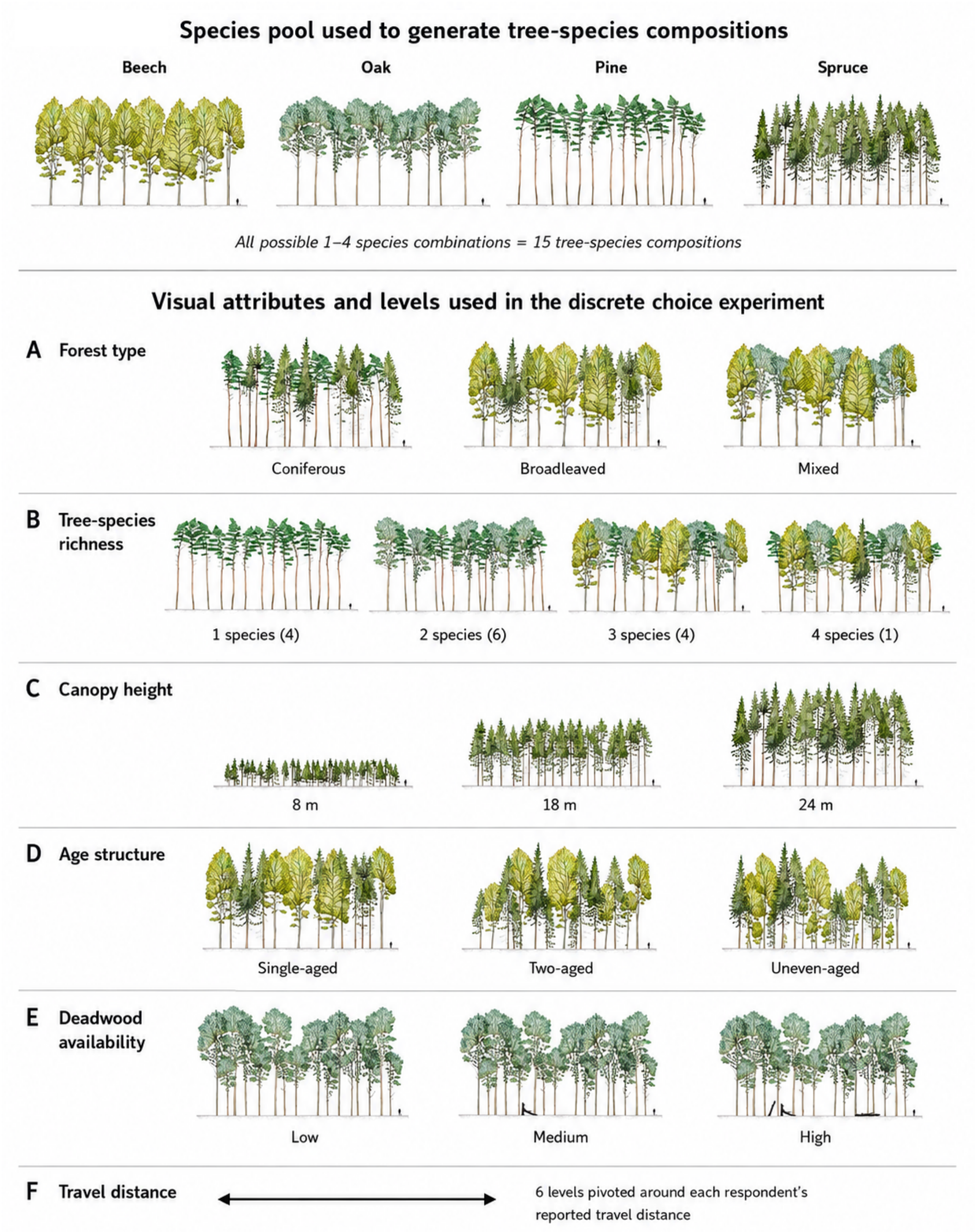

Figure 2: **Forest attributes and levels used in the visual discrete choice experiment.**

2.4 Modelling societal preferences for forest ecosystem

Societal preferences for forest structural characteristics were estimated using mixed logit models specified in willingness-to-travel (WTT) space (Train, 2009; Train and Weeks, 2005). Here, coefficients are expressed directly in units of travel distance, and represent the additional distance respondents are willing to travel for a change in forest characteristics relative to the baseline condition. The preference for forests of differing characteristics is based on the assumption that respondents choose the alternative that would provide the highest expected utility.

Utility for respondent n choosing alternative i in choice situation t was specified as:

$$U_{nit} = \alpha_n \left(X_{nit}\beta_n - Dist_{nit} \right) + \epsilon_{nit} \tag{1}$$

where X_{nit} represents the experimentally varied forest structural characteristics, β_n denotes respondent-specific WTT coefficients associated with these characteristics, $Dist_{nit}$ denotes travel distance, α_n represents the marginal disutility of travel, and ϵ_{nit} is an independently distributed random error term.

Country-specific models were first estimated to evaluate the consistency of societal preferences for forest ecosystems across Europe. A pooled European model was subsequently estimated to derive harmonized preference estimates for continental-scale spatial analyses.

2.5 Evaluating observed behavior using revealed preferences

To determine whether experimentally estimated societal preferences reflected real-world behavior, we analyzed respondents' self-reported forest visits using the travel cost method. Whereas the discrete choice experiment estimates preferences under controlled experimental conditions, this travel cost method infers values from actual visitation decisions, and therefore provides an independent behavioural assessment of the preference functions.

The analysis focused on respondents' most recently visited forest. The dependent variable was the reported number of visits to that forest during the previous year. Explanatory variables included travel distance, perceived forest ecosystem condition, and socio-demographic characteristics. Forest characteristics and travel distance were measured for the same forest that served as the reference alternative in the choice experiment.

Expected visitation levels were estimated using a zero-truncated negative binomial specification to account for overdispersion and the absence of zero-trip observations (Haab and McConnell, 2002; Cameron and Trivedi, 2013; Englin and Shonkwiler, 1995):

$$\lambda_n = \exp\left(Q_n\delta - \gamma Dist_n + X_n\beta \right) \tag{2}$$

where λ_n denotes the expected annual number of visits by respondent n to the reported forest ecosystem, Q_n represents perceived forest ecosystem condition, $Dist_n$ denotes travel distance, X_n represents socio-demographic and landscape-context variables, and δ, γ, and β are estimated parameters.

Perceived forest ecosystem condition was represented using the same five structural characteristics included in the discrete choice experiment (i.e. forest type, tree-species richness, canopy height, age structure, and deadwood availability). Landscape context was additionally characterized using the proportion of forest cover and water bodies within a 10-km buffer surrounding respondents' residences to account for variation in alternative opportunities to other forest ecosystems.

To facilitate a direct comparison with societal preference estimates, behavioural responses were additionally expressed as distance-equivalent trade-offs between forest structural characteristics and travel distance:

$$WTT_k^{RP} = -\frac{\delta_k}{\gamma} \tag{3}$$

where δ_k denotes the coefficient associated with forest characteristic k, and γ denotes the travel-distance coefficient.

Average marginal effects were also calculated to quantify expected changes in annual visitation associated with each forest characteristic:

$$ME_k = \frac{\partial E(y_n|X_n)}{\partial Q_k} \tag{4}$$

where ME_k denotes the marginal effect associated with forest characteristic k, and $E(y_n|X_n)$ denotes the expected annual number of visits to the reported forest.

2.6 Mapping the spatial distribution of societal preferences

To examine how societal preferences are distributed across Europe, pooled preference estimates from the European model were integrated with harmonized spatial information describing forest ecosystem condition.

Spatial layers that represent each of the five forest characteristics captured in the discrete choice experiment were assembled from the harmonized forest inventories, remote sensing, and conservation datasets. Specifically, the European forest domain was delineated using the broadleaved, coniferous, and mixed forest classes from the CORINE Land Cover 2018 (European Environment Agency, 2019). Forest type and tree-species richness were derived from harmonized European forest inventories (Brus et al., 2012). Canopy height was obtained from satellite–LiDAR products (Lang et al., 2023), and forest age structure from gridded National Forest Inventory datasets (Pucher et al., 2022).

Because harmonized continental-scale deadwood inventories were unavailable, deadwood availability was estimated using indicators of structural naturalness, including protected-area status and primary forest occurrence. Strictly protected areas and primary forests were assumed to contain higher levels of deadwood accumulation and structural complexity than intensively managed forests (Sabatini et al., 2021; Gustafsson et al., 2012). Consequently, this variable should be interpreted as a proxy for structural complexity and conservation-associated deadwood availability rather than direct deadwood measurements.

Forest polygons smaller than 900 ha were retained as individual analysis units, whereas larger forests were subdivided using a Voronoi-based partitioning approach to improve spatial comparability.

Societal preference estimates from the pooled European model were linked to observed forest characteristics for each spatial unit. Canopy-height effects were interpolated across observed continuous canopy height values, whereas categorical preference estimates were assigned directly to forest type, tree-species richness, age structure, and deadwood availability.

The resulting indicator, Forest Recreational Potential, for forest unit j was calculated as:

$$FRP_j = \sum_k WTT_{jk} \tag{5}$$

where FRP_j denotes Forest Recreational Potential for forest unit j, and WTT_{jk} denotes the willingness-to-travel contribution associated with forest characteristic k.

Higher values of FRP_j indicate forests whose ecological characteristics are consistently associated with stronger societal preferences. Because several combinations of forest characteristics extended beyond those explicitly represented in the discrete choice experiment, interpolation and extrapolation were required. Consequently, the resulting maps should be interpreted as relative indicators of the spatial alignment between forest ecosystem condition and societal preferences, rather than predictions of realized visitation or recreational demand.

3 Results

3.1 Society consistently prefers structurally complex forests

Societal preferences for forest ecosystem condition were notably consistent across Europe despite substantial differences in geography, forest systems, and recreational behaviour (Figure 3). Across almost all countries, respondents consistently reported the strongest preferences for forest characteristics that strongly aligned with biodiversity conservation and ecological resilience, including taller canopies, greater tree-species richness, heterogeneous age structures, and higher deadwood availability. .

Canopy height generated the strongest and most consistent responses. Forests characterized by 24 m canopies were preferred over 8 m forests in 11 of 12 countries. Willingness-to-travel (WTT) estimates associated with taller canopies ranged from approximately 7 km in Belarus to more than 50 km in Romania, although the direction of the relationship remained consistently positive across countries.

Tree-species richness also generated uniformly positive responses. Forests with higher tree-species richness consistently received higher WTT estimates than species-poor forests, irrespective of whether they were broadleaved, coniferous or mixed (i.e. forest type). While preferences for dominant forest type varied somewhat among countries, increasing compositional diversity consistently correlated with stronger societal preferences.

Age heterogeneity and deadwood availability generated smaller but generally positive responses. Uneven-aged forests were preferred over even-aged forests in nearly all countries, while forests with higher deadwood availability generally generated positive WTT estimates.

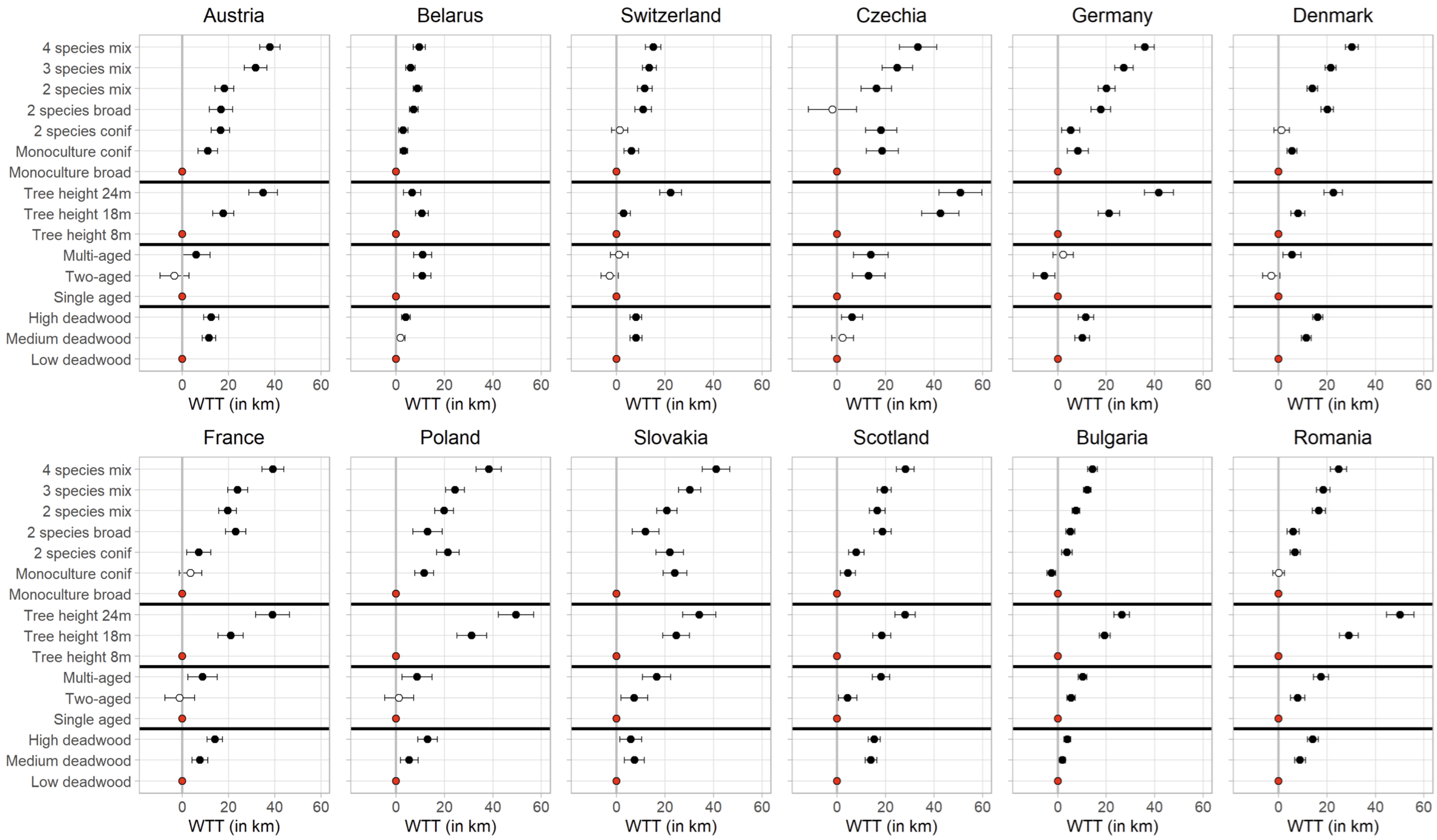

Figure 3: Country-specific willingness-to-travel estimates for forest structural characteristics.

Cross-country consistency of preference rankings

Number of countries assigning each rank within each forest attribute group

Attribute level	1st	2nd	3rd
Forest type			
Coniferous	3	1	8
Broadleaved	3	5	4
Mixed	6	6	0
Tree species richness			
2 species	0	1	11
3 species	0	11	1
4 species	12	0	0
Tree height			
8 m	0	0	12
18 m	1	11	1
24 m	11	1	0
Age structure			
Even-aged	0	5	7
Two-aged	0	7	5
Uneven-aged	12	0	0
Deadwood			
Low	0	0	12
Medium	2	10	0
High	10	2	0

Figure 4: Cross-country consistency of preference rankings based on country-specific willingness-to-travel estimates. Cells indicate the number of countries out of 12 assigning each rank to a given characteristic level. Darker shading indicates greater alignment among countries.

The ranking analysis further highlighted the consistency of societal preferences (to forest ecosystem condition) across Europe (Figure 4). Forests containing four tree species were ranked as the most preferred species-richness level in all twelve countries, while forests with taller canopies and uneven-aged structures consistently occupied the highest preference classes. High deadwood availability was also ranked positively in most countries.

Viewed holistically, these findings demonstrate that societal preferences converged strongly across Europe despite substantial ecological, geographical and cultural variation. Forest characteristics widely recognized as indicators of ecological function and integrity, and climate resilience, consistently generated the strongest public preferences across national contexts, evidenced by the alignment in relationship direction, effect sizes and ranking of preference estimates.

3.2 Observed behaviour independently support societal preferences

Observed behaviour closely mirrored the societal preferences identified in the discrete choice experiment (Figure 5). Forest characteristics that generated the strongest societal preferences also consistently generated higher visitation frequencies and stronger willingness-to-travel estimates in the travel cost model.

Behavioural responses were strongest for canopy height and tree-species richness. Taller forests generated substantially higher WTT estimates in both models for societal preferences and observed behavior, and were associated with increased visitation frequency. Similarly, increasingly tree-species richness consistently produced positive responses across all behavioral indicators.

Age heterogeneity and deadwood availability generated smaller but generally positive behavioral responses. Multi-aged forests were associated with higher expected visitation frequency, and positive WTT estimates. Forests with greater deadwood availability also generated positive responses, although effect sizes were smaller than those observed for canopy height and species richness.

Although uncertainty was greater for estimates from the observed behavior than for the societal preference models, the relative ranking of forest characteristics remained highly consistent between approaches. Forest characteristics generating the strongest societal preferences also generated the strongest behavioral responses, demonstrating that experimentally estimated societal preferences were independently reflected in observed behavior.

To illustrate the cumulative contribution of forest ecosystem condition, we examined a sequential transition from structurally simplified forests characterized by short, species-poor, even-aged stands with low deadwood availability to structurally complex forests characterized by taller canopies, greater species richness, uneven-aged structure, and higher deadwood availability (Figure 6).

This transition generated increases of approximately 94 km in willingness-to-travel for societal preferences, and approximately 119 km in willingness-to-travel for observed behaviour. It was also associated with an increase of approximately 4.3 annual forest visits per respondent. Across all indicators, increases in canopy height and tree-species richness contributed the largest responses, while age heterogeneity and deadwood availability contributed smaller but consistently positive effects.

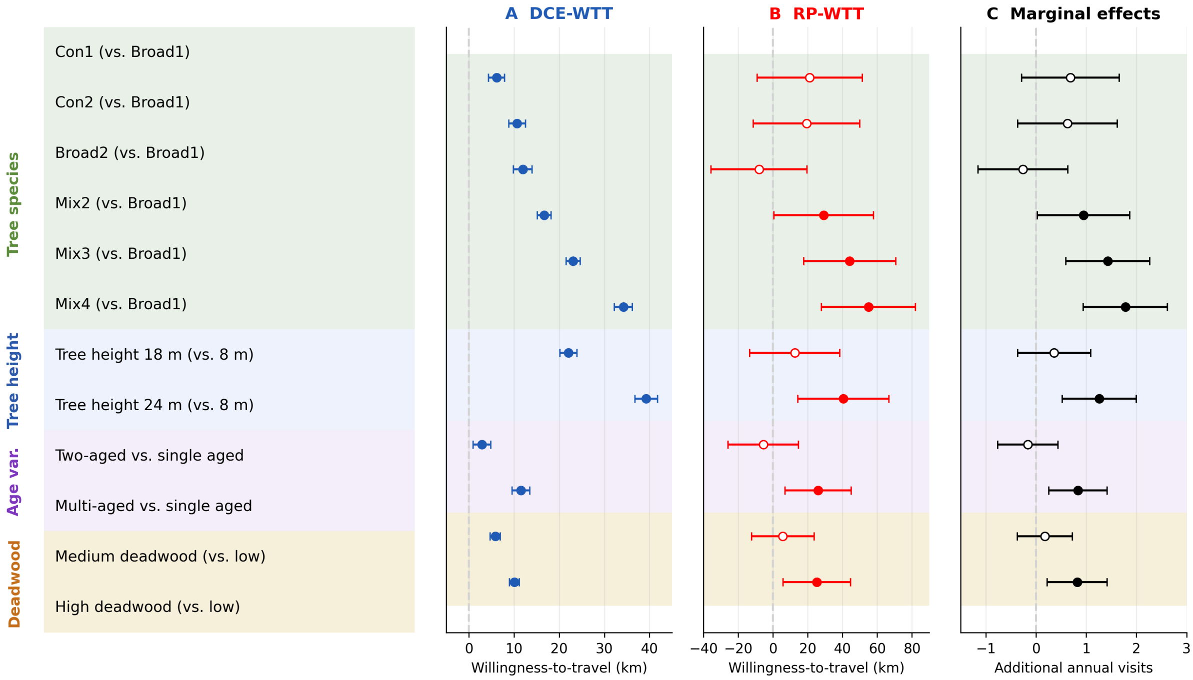

Figure 5: Comparison of recreational responses associated with forest ecosystem condition. Panel A shows willingness-to-travel estimates derived from the discrete choice experiment (DCE-WTT), Panel B shows distance-equivalent estimates derived from the visitation model (RP-WTT), and Panel C shows marginal effects on annual visitation frequency. Points indicate parameter estimates and horizontal bars represent 95% confidence intervals.

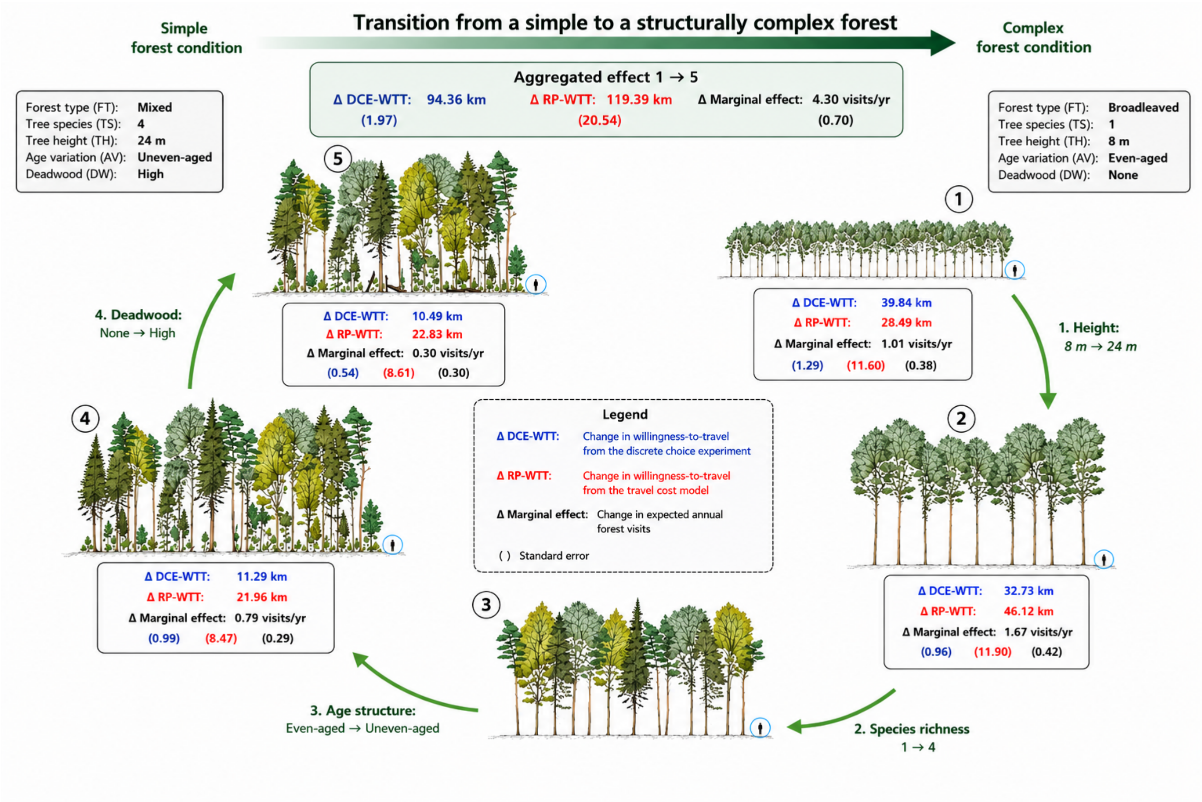

Figure 6: Illustrative transition from structurally simplified to structurally complex forests and associated changes in recreational responses. Values represent stated preferences (DCE-WTT), responses (RP-WTT), and marginal effects on annual visitation frequency.

These findings indicate that societal preferences associated with forest ecosystem condition are reflected not only in experimentally-derived choices, but also in observed forest-visiting behaviours, providing strong evidence that the observed patterns extend beyond hypothetical decision-making.

3.3 Forest recreation provides a continent-wide expression of societal preference

Forest recreation was widespread across all twelve European countries despite substantial differences in accessibility, visitation frequency, and recreational activities (Figure 7). These differences illustrate the broad environmental, geographical and cultural gradients, providing a strong evidence base to evaluate whether societal preferences for forest ecosystem condition converge across Europe.

The proportion of respondents reporting at least one forest visit during the previous year ranged from 65% in Romania to 90% in Switzerland and Poland. Average annual visitation frequency ranged from approximately 9 visits per person in Belarus to 55 visits in Switzerland, while the annual duration spent in forests ranged from approximately 19 hours in Belarus to more than 100 hours in Switzerland.

Accessibility also differed substantially among countries. The average round-trip travel distances ranged from approximately 5 km in Switzerland to 29 km in Scotland, while the proportion of visits undertaken by walking or cycling ranged from 14% in Belarus to 62% in Switzerland. Countries with shorter travel distances generally exhibited higher visitation frequencies and greater reliance on active transport.

Distinct recreational profiles emerged among countries. Alpine and Central European countries generally combined relatively high accessibility, high participation rates and frequent forest visits, whereas countries characterized by longer travel distances tended to exhibit lower visitation frequencies. Recreational activities were more heterogenous. While nature observation was consistently reported across countries, activities such as mushroom foraging varied substantially, reflecting differences in recreational preferences and forest use.

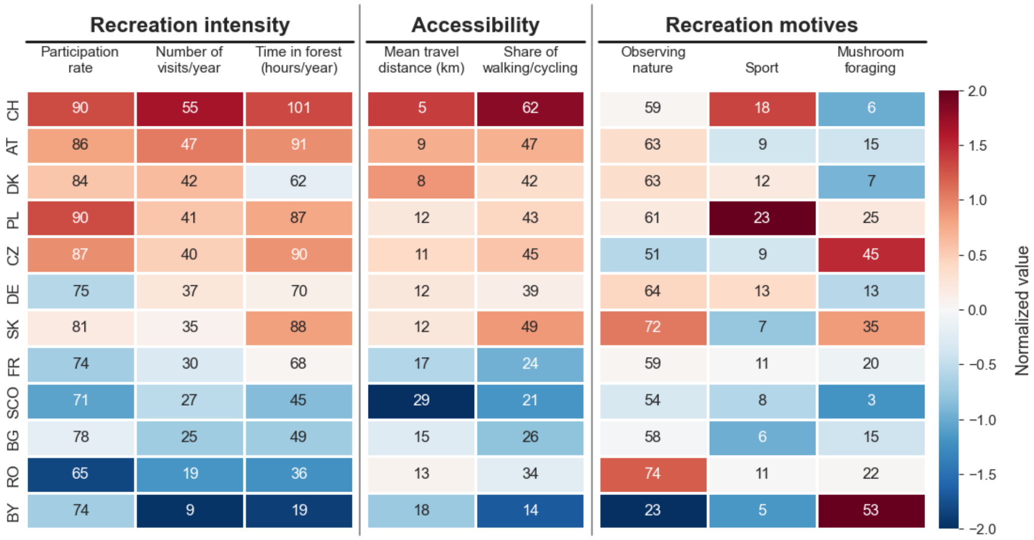

Figure 7: Forest recreation profiles across twelve European countries. Cell values represent country-level statistics. Colors indicate standardized values (z-scores), with warmer colors denoting values above and cooler colors denoting values below the cross-country mean. Travel distance was reverse-coded so that warmer colors indicate greater accessibility.

3.4 Mapping the spatial convergence of ecological condition and societal preferences

Integrating harmonised societal preference estimates with continental-scale forest inventories and remote-sensing datasets revealed substantial spatial variation in the alignment between forest ecosystem condition and societal values across Europe (Figure 8). This index represents the cumulative societal preferences associated with measurable dimensions of forest ecosystem condition, including forest type, tree-species richness, canopy height, age structure, and deadwood availability.

Estimated FRP ranged from less than 10 km in structurally simplified forests to more than 120 km in forests characterized by favourable combinations of structural and compositional characteristics. High values were concentrated primarily within mountain and upland landscapes, including the Alps, Carpathians, Bavarian Forest, Bohemian Forest, and parts of the Scottish Highlands. These landscapes were characterized by forest conditions consistently associated with both ecological function and integrity and stronger societal preferences, , including taller canopies, greater tree-species richness, heterogeneous age structures, and higher deadwood availability. Conversely, lower FRP values were generally associated with intensively managed forests characterized by lower structural diversity, younger stands, and reduced ecological heterogeneity.

The average FRP also varied substantially between countries. It ranged from approximately 56 km in Scotland to approximately 86 km in Switzerland, with relatively high average values observed in Austria, Slovakia, Germany, Romania, and Czechia (Figure/Table XX).

The spatial analyses further demonstrated that forest cover alone provides limited

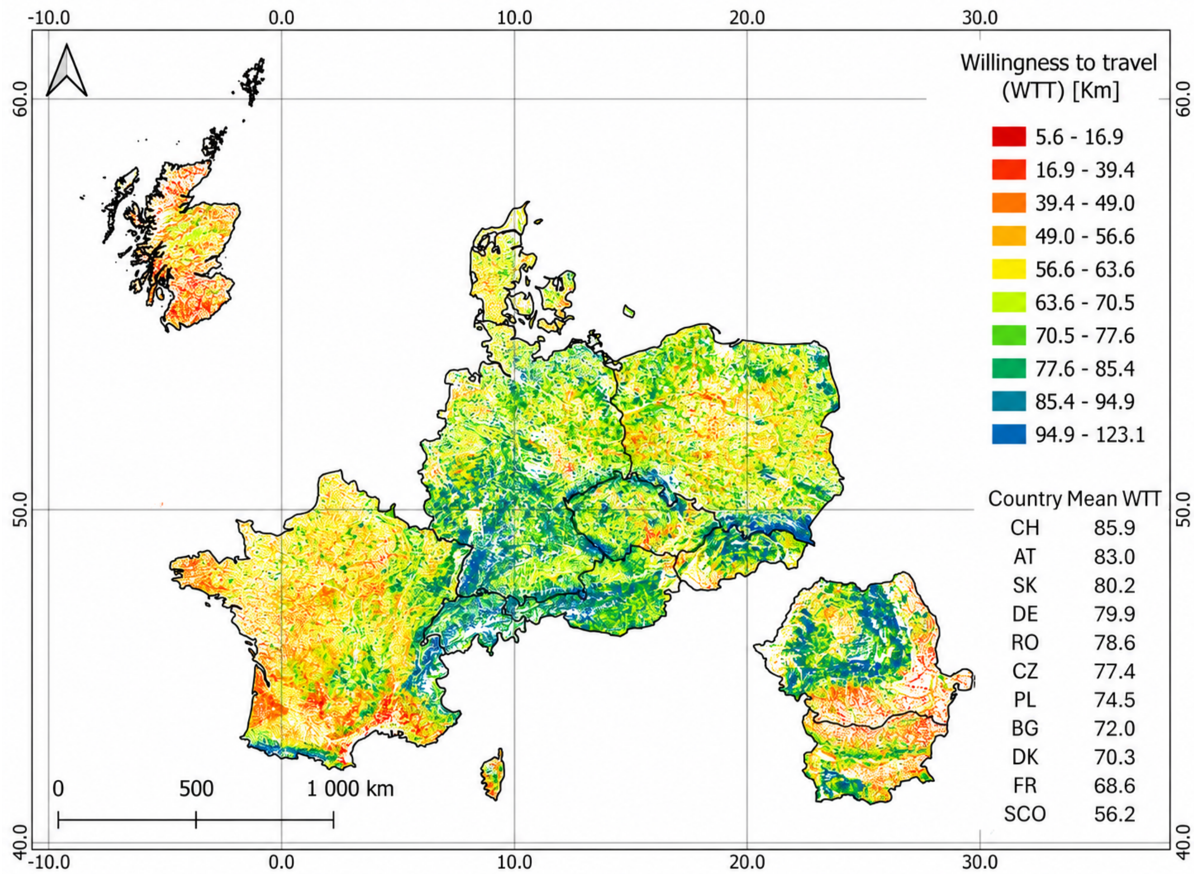

Figure 8: Spatial distribution of Forest Recreational Potential (FRP) across European forests. The index was derived by integrating pooled willingness-to-travel estimates with harmonized spatial data describing forest ecosystem condition. Higher values indicate forests with greater recreational potential based on their structural characteristics. Colors represent Forest Recreational Potential expressed as equivalent willingness-to-travel (km), while inset values indicate country-level mean FRP.

information about societal preferences[CHECK]. Forests occupying similar areas often differed substantially in estimated FRP because societal preferences were driven primarily by forest ecosystem condition rather than forest cover itself. Consequently, variation in forest quality generated substantially greater differences in societal preferences than variation in forest cover alone. Taken together, these findings demonstrate that forest characteristics for stronger biodiversity conservation and climate resilience are also those most consistently preferred by society across Europe. The resulting maps therefore identify landscapes where ecological integrity and societal preferences converge to provide a spatially explicit representation of socio-ecological opportunity for biodiversity conservation, climate adaptation, and multifunctional forest governance across European forests.

4 Discussion

Convergence between biodiversity-oriented forest management and societal values The central finding of this study is that forest characteristics widely promoted to enhance biodiversity conservation and climate resilience are also those most consistently valued by society across Europe. Across twelve countries spanning diverse ecological, geographical and cultural contexts, respondents consistently preferred forests characterised by taller canopies, greater tree-species richness, heterogeneous age structures and higher levels of structural naturalness. These preferences were remarkably stable despite pronounced differences in forest accessibility, recreational traditions and visitation patterns, suggesting that societal responses to forest ecosystem condition are considerably more transferable across Europe than previously recognised. This finding challenges a long-standing assumption in forest policy that biodiversity-oriented management necessarily conflicts with societal preferences. Forest management often involves perceived trade-offs between ecological integrity and public acceptance, particularly where interventions such as deadwood retention, longer rotations or reduced harvesting alter the appearance of forests. However, our results suggest that many structural characteristics promoted to increase ecological resilience are simultaneously associated with stronger societal preferences. Rather than representing competing objectives, biodiversity conservation, climate adaptation and societal values frequently converge around the same forest conditions.

Our findings are consistent with an expanding body of research showing that people respond most positively to forests perceived as natural, biodiverse and structurally complex (Edwards et al., 2012; Giergiczny et al., 2015; Filyushkina et al., 2017; Sacher et al., 2022). Across Europe, structually heterogenous, natural-looking forests are consistently associated with greater aesthetic appreciation, restorative experiences and recreational satisfaction (McElhinny et al., 2005; Ehbrecht et al., 2017; Seidel et al., 2019). These responses likely reflect richer sensory environments, greater visual complexity, and stronger perceptions of ecological integrity associated with mature forests, suggesting that structural complexity influences not only ecosystem functioning but also how people experience and value forest landscapes (Tang et al., 2015). Importantly, the societal benefits of structurally complex forests extend beyond recreation. Mature forests with diverse canopies substantially moderate microclimates, reducing physiologically equivalent temperatures by 12.1 to 14.5°C under conditions of strong to extreme heat stress, with forest structure and tree-species composition emerging as primary determinants of cooling capacity (Gillerot et al., 2022). These cooling services are becoming increasingly important as climate change intensifies the frequency, duration, and intensity of heatwaves globally (IPCC, 2021). In Europe, heatwaves already represent the deadliest weather-related natural hazard, and between 27% and 63% of the population is projected to be exposed to extreme heat by the end of the century, with heat-related mortality increasing substantially under business-as-usual conditions (Forzieri et al., 2017). As such, forests with characteristics that enhance biodiversity and climate resilience may also strengthen the capacity of forest ecosystems to protect human health, in addition to providing environments that people actively value and use. Our study extends these insights by demonstrating that these relationships are remarkably consistent across Europe. Previous evidence has largely been derived from individual countries or local landscapes, making it difficult to distinguish universal responses from context-specific preferences. By combining harmonized measures of societal preferences and observed behaviour across twelve European countries, we show that appreciation for ecologically mature forests transcends substantial differences in geography, forest composition, recreational traditions, and accessibility. This convergence suggests that structural complexity represents a broadly shared societal value, strengthening the case for biodiversity-oriented forest management as a strategy capable of simultaneously supporting ecological resilience, climate adaptation, and human well-being.

Human preferences do not necessarily translate into behaviour, as behaviour is shaped by multiple factors, ranging from individual values and attitudes to social and contextual constraints such as accessibility, infrastructure, and social norms (Sockhill et al., 2022; Ajzen, 1991; Fielding and Hornsey, 2026). Consequently, relying on stated preferences alone provides an incomplete basis for understanding how people interact with forest ecosystems in reality.

A major contribution of this study is therefore the independent evaluation of societal preferences using observed behaviors. Across Europe, the same forest characteristics that generate the strongest societal preferences also generated the highest visitation frequences and revealed willingness-to-travel estimates, particularly for canopy height and tree-species richness (Figure xx). Although uncertainty was greater for the behavioral models, the overall ranking remained strikingly similar between both experimental and observed approaches. This distinction is particularly important because forest visits represent one of the most widespread forms of everyday interaction between people and nature in Europe (Živojinović et al., 2026). Forests are visited for diverse purposes, including recreation, physical activity, relaxation, social interaction, and engagement with nature (Živojinović et al., 2026). Exposure to natural environments has been associated with psychological restoration, physical activity, reduced stress, and stronger nature connectedness (Hartig et al., 2014; Wyles et al., 2019). Consequently, encouraging visits to structurally complex forests may generate benefits extending well beyond recreation alone.

The observed preference patterns are also consistent with ecological research linking structural diversity and tree-species richness to biodiversity, resilience, and ecosystem multifunctionality (Messier et al., 2013; Forrester and Bauhus, 2016; Bauhus et al., 2017; Messier et al., 2022). These results therefore suggest that forest structures increasingly promoted for ecological reasons are not perceived negatively by the public; rather, they are generally associated with more attractive and preferred forest environments.

4.1 Integrating societal values into forest governance

This study also demonstrates how societal values can be integrated into ecological monitoring across large spatial scales. Specifically, we combined behavioural analyses with harmonized forest inventories and remote-sensing datasets to directly map societal preferences on to measurable forest ecosystem condition rather than broad landcover classes. This represents an important advance over existing assessments of cultural ecosystem services, which often infer recreational value from accessibility or visitation alone, while treating forests as ecological homogeneous. Our approach instead links societal preferences directly on to ecological characteristics that can be monitored using forest inventories and remote sensing. As harmonized ecological monitoring continues to improve across Europe, opportunities to integrate ecological condition with societal values will become increasingly important for adaptive forest governance. Such approaches could help identify landscapes where restoration simultaneously enhances biodiversity conservation, climate resilience and human well-being, while also highlighting areas where ecological and societal priorities diverge and require explicit deliberation.

4.2 Implications for governing multifunctional forest under global change

European forests are entering a period of unprecedented ecological and climatic transformation. Climate warming, drought, bark beetle outbreaks, wildfire and wind disturbance are increasingly altering forest structure and composition, requiring widespread adaptation of management practices (Seidl et al., 2017; Senf and Seidl, 2021). As such, contemporary forest governance increasingly seeks to balance multiple priorities, such as biodiversity conservation, climate resilience, carbon storage, timber production and human health and well-being. Our findings suggest that these conservation, climate and human health priorities may be more compatible than often assumed. Many interventions promoted under close-to-nature silviculture, including increasing tree-species diversity, retaining older trees, extending rotation lengths and maintaining structural heterogenetic can enhance ecological and climate resilience while promoting positive experiences and engagement with forests simultaneously. These findings suggest that forest management strategies promoting structural complexity may generate synergies between ecological objectives and recreational values rather than creating unavoidable trade-offs. Likewise, initiatives under the EU Forest Strategy for 2030 and the Nature Restoration Regulation emphasise restoring structurally diverse forests capable of sustaining biodiversity and ecosystem resilience. Our results indicate that these ecological transitions are likely to retain, and in many cases enhance, the qualities that people value in forests.

This has important implications for public acceptance and health and wellbeing. Successful conservation increasingly depends not only on the effectiveness of targeted interventions, but also on societal legitimacy. Forests that simultaneously support biodiversity, climate adaptation and positive human experiences may reduce many of the conflicts traditionally associated with multifunctional forest management. Rather than framing conservation and recreation as competing land-use objectives, our findings suggest that they can often be pursued through the same management actions. Successful conservation may also contribute to public health and well-being by providing opportunities for nature-based activities that promote physical activity and support physical, mental, and social health (Shanahan et al., 2019). Importantly, our results do not imply that all management objectives are universally aligned. Trade-offs will inevitably arise where timber production, recreation, biodiversity conservation and climate adaptation compete for limited space or resources. Nevertheless, our findings demonstrate that one of the most widely assumed trade-offs—that biodiversity-oriented forest management necessarily diminishes public appreciation—is considerably weaker than commonly believed.

4.3 Limitations and future research

Several limitations should be acknowledged. First, societal preferences were estimated using visual representations of forests. Although these images were realistic and enabled systematic manipulation of ecological characteristics under controlled experimental conditions, actual forest experiences also involve soundscapes, seasonal dynamics, biodiversity encounters and social interactions that were beyond the scope of this study.

Second, observed behaviour was self-reported by respondents' to their most recently visited forest, which captures only a snapshot of the many forests that they might visit in the same year. While this provided an independent behavioural assessment of societal preferences, future studies could incorporate longitudinal approaches such as repeated visitation records or mobile sensing to provide an understanding of how ecological conditions shape forest visits behavior across time.

Finally, future research should examine how societal preferences evolve as forests increasingly experience climate-driven changes and disturbances. Understanding whether public responses differ following acute events such as drought, wildlife, or pest outbreaks or long-developing events such as structural transformation, will become increasingly important as restoration and adaptation reshape European forest landscapes.

5 Conclusions

European forests are undergoing rapid transformation as biodiversity loss, climate change and increasing societal demands reshape priorities for forest management. A central challenge is to determine whether ecological interventions that promote biodiverse, resilient forests align with the values and behaviors of the people who use them. Across twelve European countries, we found that forests characterized associated with biodiversity conservation and climate resilience, including taller canopies, greater tree-species richness, heterogeneous age structures, and presence of deadwood, were consistently associated with stronger societal preferences. These preferences were notably stable despite substantial differences in ecological conditions, recreational cultures, and accessibility among countries. Crucially, they were independently supported by observed recreational behaviour, demonstrating that societal preferences translated into actual forest use.

The consistency of these relationships across diverse ecological and cultural contexts, together with broad support from observed visitation behaviour, suggests that key dimensions of recreational responses to forests are more transferable across large environmental gradients than often assumed.

By integrating preference estimates and behaviour analyses with harmonized forest inventories and remote-sensing data, we further demonstrate how societal preferences can be translated directly to measurable indicators of forest ecosystem condition, and mapped consistently across continental spatial scales. This provides an analytical pipeline to identify where ecological integrity and societal values converge, moving beyond assessments based solely on forest extent or land-cover classes. We also showed that the ecological quality of forests and not simply forest cover, was key to predicting people's engagement with forests.

Our findings challenge the commonly assumed trade-off between biodiversity-oriented forest management and public preferences. Instead, they suggest that many management actions promoted to enhance ecological resilience—including increasing structural complexity, tree-species diversity, and structural naturalness—are also those most consistently valued by society. While trade-offs will inevitably remain among competing forest objectives, biodiversity conservation, climate adaptation, and societal needs should not be viewed as inherently conflicting goals. As Europe implements ambitious restoration and climate adaptation policies, integrating ecological and social evidence will become increasingly important for securing both ecological effectiveness and public support. Our study demonstrates that biodiversity-oriented forest management can simultaneously strengthen ecological resilience and align with the ways people value and engage with forests, providing a stronger foundation for adaptive and multifunctional forest governance under global environmental change.

Supplementary Information

A Survey design and visual choice experiment

A.1 Sampling and questionnaire

Data were collected using online survey panels in twelve European countries: Austria, Belarus, Bulgaria, Czechia, Denmark, France, Germany, Poland, Romania, Scotland, Slovakia, and Switzerland. Quota sampling was used to approximate national population distributions with respect to age, gender, region, and settlement size. Only respondents who had visited a forest at least once during the previous 12 months were eligible to participate. The final dataset contained 11,622 respondents.

The questionnaire collected information on: (i) recent forest visitation behaviour, (ii) responses to the visual discrete choice experiment (DCE), (iii) recreational activities undertaken during forest visits, and (iv) socio-demographic characteristics.

A.2 Visual choice experiment

The DCE quantified recreational preferences for forest ecosystem condition using realistic visualizations of forest stands. Attributes represented forest type, tree-species richness, canopy height, age structure, deadwood availability, and travel distance.

Table 1: Attributes and levels included in the visual discrete choice experiment.

Attribute	Levels
Forest type	Broadleaved, coniferous, mixed
Tree-species richness	1, 2, 3, 4 tree species
Canopy height	8 m, 18 m, 24 m
Age structure	Single-aged, two-aged, uneven-aged
Deadwood availability	Low, medium, high
Travel distance	Pivoted around respondents' reported travel distance

Travel distance was pivoted around the distance reported for each respondent's most recent forest visit. This anchored hypothetical alternatives in respondents' own recreational context and allowed preference estimates to be expressed in willingness-to-travel units.

Choice tasks were generated using a Bayesian D-efficient design (Huber and Zwerina, 1996; Rose and Bliemer, 2009; Bliemer et al., 2008). Prior parameters were obtained from a pilot survey. The final design consisted of 36 choice situations divided into three blocks, with each respondent completing 12 choice tasks. Each task included one reference alternative corresponding to the respondent's most recent forest visit and two hypothetical forest alternatives.

B Preference modelling

B.1 Mixed logit model in willingness-to-travel space

Recreational preferences were estimated using mixed logit models specified directly in willingness-to-travel (WTT) space (Train, 2009; Train and Weeks, 2005). Utility for respondent n, alternative i, and choice situation t was specified as:

$$U_{nit} = V_{nit} + \varepsilon_{nit}, \tag{6}$$

where ε_{nit} is an independently and identically distributed extreme-value error term. The deterministic utility component was:

$$V_{nit} = \alpha_n \left(X_{nit}\beta_n - Dist_{nit} \right), \tag{7}$$

where $Dist_{nit}$ denotes travel distance, X_{nit} is a vector of forest structural characteristics, β_n represents respondent-specific WTT parameters, and α_n represents the marginal disutility of travel.

Conditional on parameter values, the probability that respondent n chooses alternative i in choice situation t is:

$$P_{nit} = \frac{\exp(V_{nit})}{\sum_j \exp(V_{njt})}. \tag{8}$$

The unconditional probability of the observed sequence of choices $y_n = [y_{n1}, y_{n2}, \ldots, y_{nT}]$ is obtained by integrating over the joint distribution of random parameters:

$$P(y_n) = \int \prod_t \left(\frac{\exp(V_{ny_{nt}t})}{\sum_j \exp(V_{njt})} \right) \phi(\beta_n, \alpha_n \mid \Omega)\, d(\beta_n, \alpha_n), \tag{9}$$

where $\phi(\beta_n, \alpha_n \mid \Omega)$ denotes the joint density of random coefficients parameterized by Ω.

Preference heterogeneity was represented using random parameters. WTT coefficients were assumed to follow normal distributions:

$$\beta_n \sim N(\mu, \Sigma), \tag{10}$$

while the travel disutility parameter was constrained to remain positive using a log-normal distribution:

$$\alpha_n \sim LN(\mu, \sigma). \tag{11}$$

Models were estimated using simulated maximum likelihood with quasi-Monte Carlo draws. Country-specific models were estimated to assess cross-country consistency, and a pooled European model was used for spatial mapping.

C Behavioural consistency analysis

C.1 Visitation model

Observed recreational behaviour was analysed using a zero-truncated negative binomial visitation model, consistent with count-data approaches used in recreation-demand analysis (Haab and McConnell, 2002; Parsons, 2003; Cameron and Trivedi, 2013; Englin and Shonkwiler, 1995). The dependent variable was the reported annual number of visits to the respondent's most recently visited forest.

Expected visitation frequency for respondent n was specified as:

$$\lambda_n = \exp\left(X_n\beta - \gamma TC_n\right), \tag{12}$$

where TC_n denotes individual travel cost or travel distance, X_n is a vector of perceived forest characteristics and respondent characteristics, β is a vector of estimated coefficients, and γ captures the effect of travel effort on expected visitation frequency.

The probability mass function of the zero-truncated negative binomial model is:

$$P(y_n) = \frac{\Gamma\left(y_n + \frac{1}{\alpha}\right)}{\Gamma(y_n+1)\Gamma\left(\frac{1}{\alpha}\right)} \frac{p_n^{1/\alpha}}{1 - p_n^{1/\alpha}} (1-p_n)^{y_n}, \tag{13}$$

where

$$p_n = \frac{1}{1+\alpha\lambda_n}, \tag{14}$$

and α denotes the overdispersion parameter.

C.2 Distance-equivalent behavioural responses

Distance-equivalent behavioural responses were derived from visitation-model coefficients as:

$$RP\text{-}WTT_k = -\frac{\beta_k}{\gamma}. \tag{15}$$

Average marginal effects were additionally calculated to express the association between perceived forest characteristics and expected annual visitation frequency.

D Spatial forest datasets and harmonization

Spatial indicators of forest ecosystem condition were assembled from harmonized European forest inventory, remote-sensing, and conservation datasets. Spatial datasets were selected to represent the forest attributes evaluated in the DCE.

Table 2: Spatial datasets used to characterize forest ecosystem condition.

Variable	Source	Resolution
Forest type	CORINE Land Cover 2018	100 m
Tree-species richness	European tree species distribution data	1 km
Canopy height	ETH Global Canopy Height Map	10 m
Age structure	European forest structure dataset	8 km
Protected areas	Natura 2000 / WDPA / Emerald Network	Polygon
Primary forest occurrence	European primary forest dataset	Polygon / rasterized

The European forest domain was delineated using CORINE Land Cover classes 311, 312, and 313, corresponding to broadleaved, coniferous, and mixed forests (European Environment Agency, 2019). Forest type and tree-species richness were derived from European tree-species distribution data (Brus et al., 2012). Canopy height was obtained from high-resolution satellite–LiDAR products (Lang et al., 2023). Forest age structure was derived from gridded European forest structure datasets (Pucher et al., 2022). Protected areas were identified using the World Database on Protected Areas and European conservation networks (Bingham et al., 2019).

Forest polygons smaller than 900 ha were retained as individual analysis units. Larger polygons were subdivided using a Voronoi-based partitioning approach to obtain more comparable spatial units across Europe. Random points were generated proportionally to polygon area, clustered using k-means, and used to construct Voronoi polygons clipped to forest boundaries.

For each forest analysis unit, spatial attributes were extracted and harmonized to the DCE attribute definitions. Forest type was assigned using the dominant CORINE forest class. Tree-species richness was assigned using the number of dominant tree species present within the corresponding spatial grid cell. Canopy height was summarized using mean canopy height within each forest unit.

Because the available spatial data identify dominant age classes rather than within-unit age variation, forest age structure was approximated using dominant stand development stage. Deadwood availability was approximated using protection status, conservation designation, primary forest occurrence, and indicators of structural naturalness. This proxy should be interpreted as an indicator of conservation-associated deadwood availability rather than a direct measurement of deadwood volume.

E Robustness and sensitivity analyses

Robustness checks included: (i) evaluation of the perceived realism of visual choice tasks, (ii) comparison of country-specific and pooled preference models, and (iii) sensitivity to the deadwood proxy.

Respondents evaluated the realism of the visual reference forests used in the choice experiment. High realism scores across countries indicated that respondents were generally able to relate the illustrations to their own forest recreation experiences.

Country-specific models were estimated to assess whether responses to forest structural complexity were broadly consistent across national samples. The pooled European model was used for spatial mapping after verifying that preference rankings were broadly similar across countries.

Deadwood availability was the only mapped forest-condition variable that could not be represented using direct harmonized spatial measurements. The main analysis therefore used protection status, conservation designation, primary forest occurrence, and indicators of structural naturalness as proxies for deadwood availability. Future work could improve this component by incorporating harmonized deadwood inventories or remote-sensing indicators of coarse woody debris when such datasets become available.

F Additional empirical results

F.1 Descriptive statistics

Table 3: Descriptive statistics for variables included in the travel cost model.

F.2 Full travel cost model results

F.3 Marginal effects from the travel cost model

F.4 Numerical values underlying Figure 5

Table 4: Truncated negative binomial travel cost model explaining annual forest visitation frequency. Reference categories are single-species broadleaved forest, 8 m tree height, single-aged forest, and low deadwood.

Variable	Coefficient	Std. error	p-value
Travel distance (km)	-0.0063	0.0004	<0.001
Forest type and species richness			
Monoculture coniferous forest	0.122	0.084	0.145
Two-species coniferous forest	0.075	0.086	0.383
Two-species broadleaved forest	-0.048	0.077	0.538
Two-species mixed forest	0.146	0.079	0.065
Three-species mixed forest	0.217	0.072	0.003
Four-species mixed forest	0.289	0.072	<0.001
Tree height			
18 m trees	0.023	0.072	0.749
24 m trees	0.178	0.072	0.013
Age structure			
Two-aged forest	-0.029	0.057	0.612
Uneven-aged forest	0.138	0.052	0.008
Deadwood			
Medium deadwood	0.035	0.050	0.484
High deadwood	0.143	0.053	0.007

Table 5: Numerical estimates underlying Figure 5. DCE-WTT denotes willingness-to-travel derived from the discrete choice experiment, RP-WTT denotes willingness-to-travel derived from the travel cost model, and marginal effects represent changes in expected annual visitation frequency. Standard errors are reported in parentheses.

	DCE-WTT		RP-WTT		Marginal effect	
Attribute	Estimate	s.e.	Estimate	s.e.	Estimate	s.e.
Conif.1 (vs. broad. mono)	6.11	0.87	19.44	13.44	0.70	0.48
Two-species conif. (vs. broad. mono)	7.67	0.89	11.92	13.65	0.43	0.49
Two-species broad. (vs. broad. mono)	12.44	1.00	-7.60	12.33	-0.28	0.45
Two-species mixed	18.07	0.76	23.31	12.74	0.84	0.46
Three-species mixed	23.05	0.79	34.64	11.69	1.25	0.42
Four-species mixed	32.73	0.96	46.12	11.90	1.67	0.42
18 m trees	22.63	1.00	3.69	11.56	0.12	0.38
24 m trees	39.84	1.29	28.49	11.60	1.01	0.38
Two-aged forest	3.50	1.01	-4.60	9.08	-0.15	0.30
Multi-aged forest	11.29	0.99	21.96	8.47	0.79	0.29
Medium deadwood	6.62	0.57	5.60	8.01	0.19	0.27
High deadwood	10.49	0.54	22.83	8.61	0.83	0.30

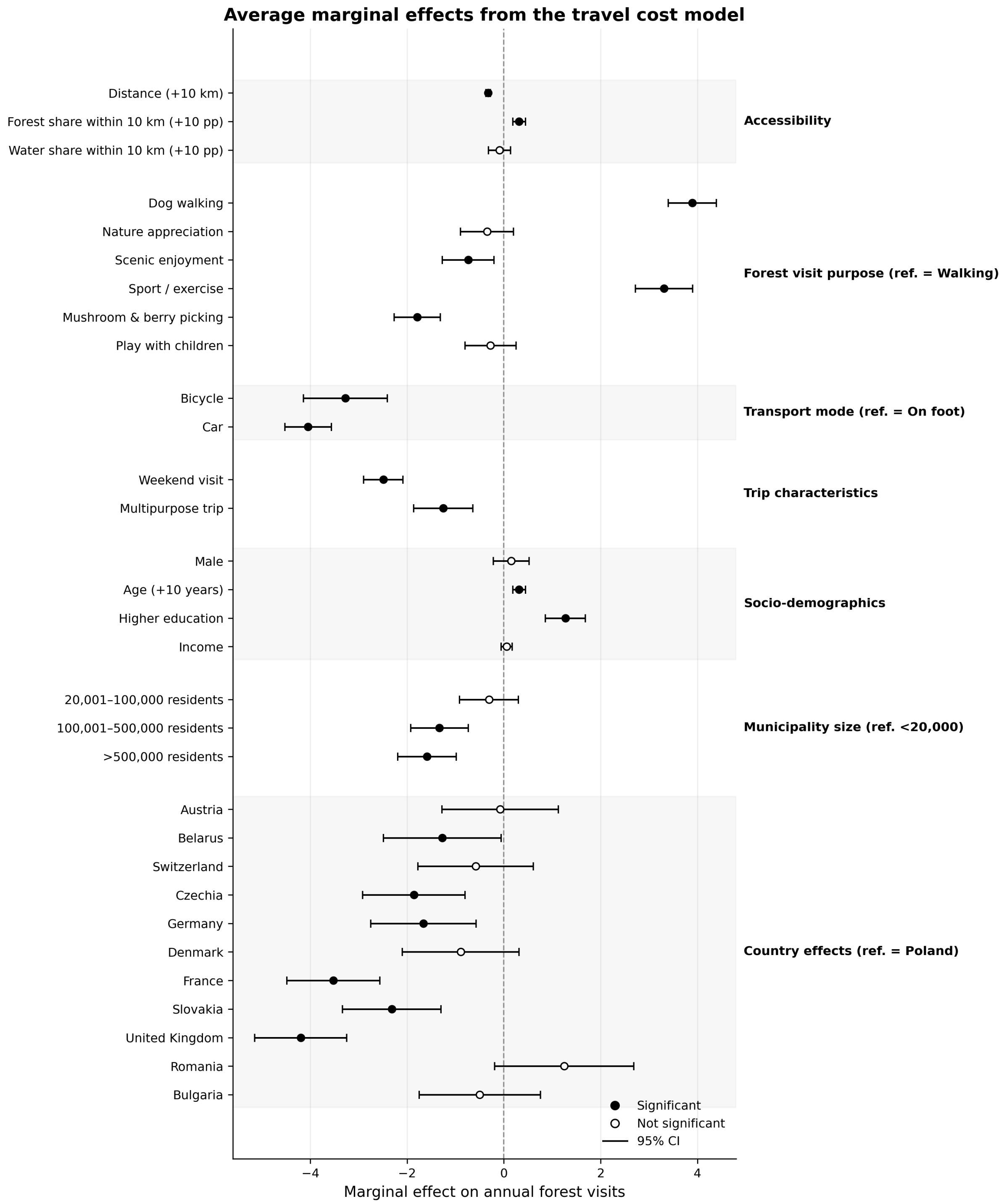

Figure 9: Average marginal effects from the truncated negative binomial travel cost model. Values represent changes in expected annual forest visitation frequency.

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