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Forests for Well-being: Exploring public preferences for forest complexity - a European perspective

Abstract

Forests are vital for outdoor recreation, benefiting mental, physical, and social well-being. However, while the importance of forest structure in supporting biodiversity and ecosystem functions is well-documented, research on its relationship with Cultural Ecosystem Services remains limited. Our study addresses this gap by estimating the aggregate annual recreational benefits provided by forests and investigating the link between forest complexity and Cultural Ecosystem Services provision. We conducted a large-scale preference survey across 12 European countries (Austria, Belarus, Bulgaria, Czechia, Denmark, France, Germany, Poland, Romania, Scotland, Slovakia, and Switzerland), involving 11,622 respondents. Our findings reveal significant positive correlations between forest complexity and satisfaction from forest visits. Preferences for older stands with diverse tree species and greater structural complexity were strongly evident across all surveyed countries. Moreover, forests with more complex structures were associated with higher annual visitation frequencies, highlighting the importance of forest quality in driving recreational engagement.

Introduction

The relationship between people and nature is a key driver for the implementation of sustainability policies and biodiversity conservation planning[1]. This relationship is rooted in cultural identities and individual and collective values such as care and stewardship[2], as well as in benefits to people such as positive experiences and good health[3–6]. Many individuals perceive nature experiences as beneficial for cognitive development, emotional enrichment, and physical and psychological health[7–13]. Frequent contacts with nature have been linked to positive perceptions of wellbeing and pro-environmental behaviours, which are essential for achieving sustainability targets[14].

Forests are among the most popular destinations for outdoor recreation, offering natural stimuli and sensory experiences with positive impacts on mental, physical, and social well-being[15–18]. These benefits entail important non-material contributions to people and potential to restoring connections with nature[19]. It is widely accepted that the provision of many ecosystem services relies on habitat structure, for example, more complex forest structures are increasingly recognized as having higher ability to support biodiversity[20–25], ecosystem stability[21,26,27], adaptability and resilience[26,28–30], forest productivity[31–34] and carbon storage capacity[35,36] to only name a few. In addition to these critical services forests also provide non-material, including the potential to experience nature. Yet, despite the extensive work on linking forest complexity, their functions and the provision of the tangible ecosystem services, there is limited research on the relationship between habitat structures and the provision of Cultural Ecosystem Services (CES) [37–40].

When studying the connection between forest structure and ecosystem services, it is essential to establish quantifiable indicators that relate ecological structures with functions and ecosystem provision. The concept of forest complexity is very useful in this regard, as it allows the decomposition of habitat structures into observable and measurable attributes[41]. Forest structural complexity is defined as a measure of the number of different attributes present and the relative abundance of each of these attributes[41]. In studying the link between forest structural complexity and the provision of CES we focus on forest structural attributes known to be associated with ecological integrity and the potential to maintain biodiversity, including: forest type, tree species richness, tree height, stand age vertical structure and presence of deadwood. At the same time it should be possible to operationalize these attributes in visitor preference surveys[20,21,23,41,42].

Existing research on linking forests structures to wellbeing comes from preference studies, with the main focus on recreation. These studies either target experts, concentrate on a restricted range of forest structural attributes, or have a narrow geographical scope[43–45]. In parallel to the preference studies there is also a growing body of evidence indicating that the exposure to forests has positive both physical and mental health outcome[6,15–18]. Yet, the evidence on the link between forest structures and exposure to nature is lacking.

Our study aims to contribute to filling this gap by firstly examining the magnitude of recreational benefits from forest recreation and secondly by investigating the relationship between forest complexity and the provision of CES. Our specific research questions are: (1) What are the aggregated national recreational benefits provided by forests? and (2) Does satisfaction from visiting forests and exposure to forests, measured by the number of forest visits people make, depend on forest complexity?

To address these questions, we developed a large-scale preference survey. The standardized survey instrument was conducted on nationally representative samples from 12 European countries (Austria, Belarus, Bulgaria, Czechia, Denmark, France, Germany, Poland, Romania, Scotland, Slovakia, and Switzerland), involving 11,622 respondents in total.

Approach

The analysis is composed of two main parts. The first part is rooted in the Travel Cost Method (TCM)[46] and aims to estimate the national recreational benefits provided by forests. To achieve this, we estimated the value per average forest visit (consumer surplus per person/trip) and calculated the total number of forest visits made in each of the studied countries over a one-year period. To avoid confounding recreational benefits with other benefits, we focused solely on one-day, single-purpose forest visits, providing a conservative estimate of forest recreational benefits at the national level.

In the second part we test the main hypothesis of our paper that people's satisfaction with forest visits and the frequency of visits are positively correlated with forest complexity. To test our hypothesis, we developed a preference survey comprising Revealed (RP) and Stated Preference (SP) sections, as illustrated in Figure 1.

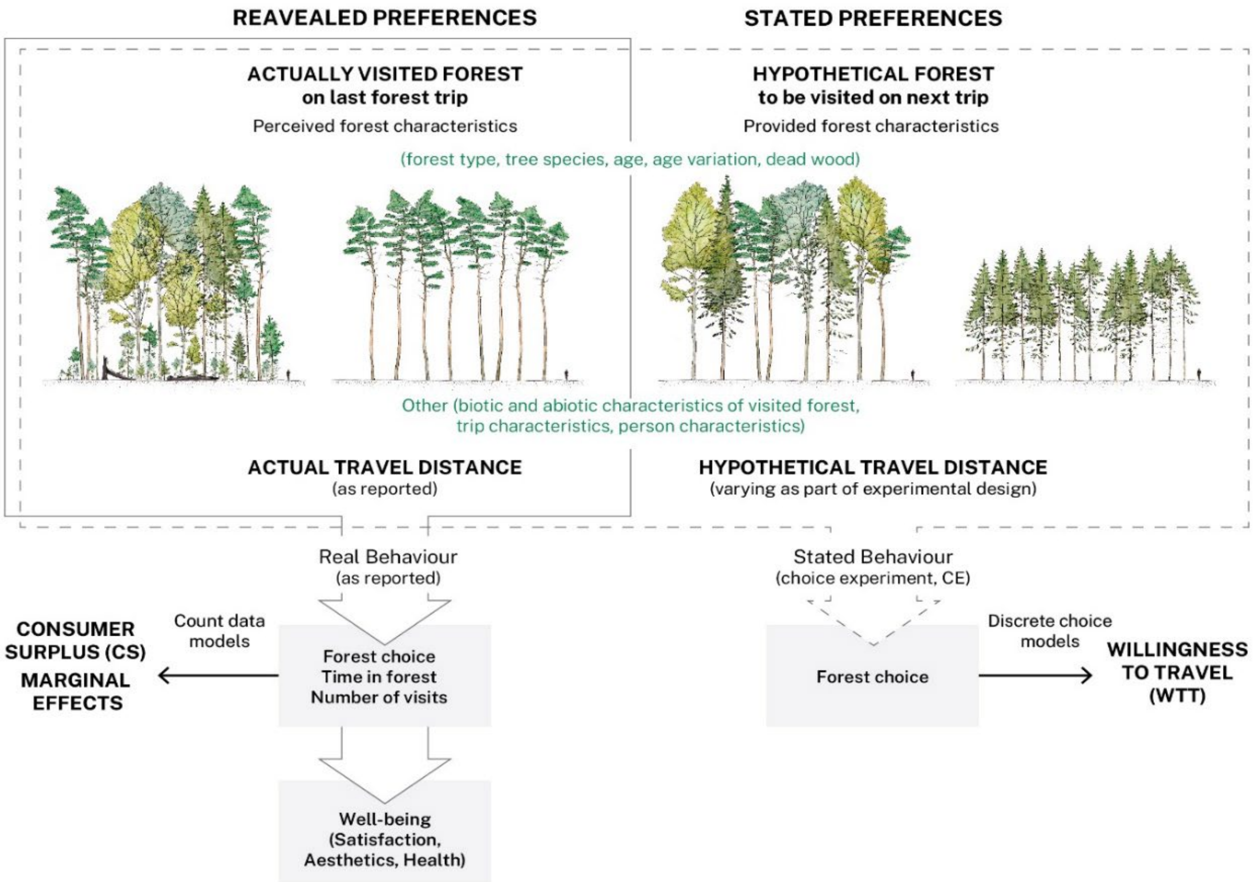


Fig. 1. **Methodological Framework**. In the Revealed Preference section, respondents provided details of their latest forest visit, enabling the estimation of average consumer surplus per forest trip. Through visual aids, respondents delineated the characteristics of the last forest visit, facilitating an exploration of the correlation between these traits and visit frequency. In the Stated Preference part, respondents chose between their most recent forest visit and two hypothetical forests, each differing in characteristics and travel distances. These choices formed the basis for estimating the Willingness to Travel for forest characteristics.

The questionnaire consisted of four parts. In the first part, respondents provided information about their last visited forest, including its location, travel distance, number of visits, and the activities undertaken there. This information was used to estimate country-specific recreational benefits.

In the second part, respondents described the perceived structural features of their last visited forest using visual aids, which ranged from plantation-like to close-to-natural stands. This information was later used to visualize the forests in the Discrete Choice Experiment (DCE) section and to explore the link between forest structures and the number of visits with marginal effect (i.e., additional visits due to changes in forest characteristics) serving as an indicator.

In the third part, participants engaged in a Discrete Choice Experiment (DCE), where they compared their most recent forest visit to two hypothetical forests with differing characteristics and travel distances. To ensure the survey closely reflected actual behaviour, participants were instructed to choose their preferred forest for their next trip within the same context and motivations as their last described forest visit. Using discrete choice models, we estimated the Willingness to Travel (WTT), expressed in kilometres, for each attribute level, representing the maximum distance individuals would be willing to travel to visit a forest with specific characteristics. In economic terms, WTT is a measure of the utility (satisfaction) individuals derive from visiting forests with given characteristics. This satisfaction may extend beyond immediate enjoyment from experiencing nature and may offer longer-term benefits, including stress relief, relaxation, and positive health outcomes, among others[8,13,18,47], which we collectively term as benefits contributing to well-being (Figure 1).

Finally, in the fourth part, we validated the SP and RP results through direct preference assessment in a subset of countries in which respondents were asked to choose the most and least preferred levels for each forest attribute.

Patterns in outdoor forest recreation

In all studied countries but Romania, the share of individuals who embarked on at least one forest visit primarily driven by recreational motives in the last 12 months was larger than 70% (Fig. 2b) indicating that forests play a significant role for outdoor recreation. We also see that the studied countries vary largely in the average number of annual visits spanning from 9 in Belarus to 55 in Switzerland (Fig. 2b), with a higher frequency of forest visits being reported in Western-Central Europe. We also find a substantial degree of heterogeneity in the average distances of the last visited forests, with values ranging from 6 kilometres in Switzerland to 29 kilometres in Scotland (round trip). Such pronounced disparities may indicate substantial differences among the surveyed countries in terms of forest availability that meets people’s expectations for recreation.

The choice of transportation mode is closely linked to the distance required to reach the forest. Walking or biking (see Fig. 2b) are popular choices for short-distance trips, with the percentage of respondents using these modes ranging from 14% in Belarus to 62% in Switzerland (with an average of 36% across all countries). Importantly, individuals who stated walking or biking to the last visited forest had a significantly higher number of visits in the last 12 months (18.2 visits/year compared to 7.2 visits/year to respondents who travelled by car). Consequently, although constituting only 36% of respondents, this group accounted for 60% of all reported forest visits in our sample, varying from 22% in Belarus to 78% in Switzerland.

Forest visits encompass a variety of outdoor activities like dog-walking, sports (such as running, cycling, cross-country skiing, and horseback riding), outings with children, and gathering mushrooms and berries. Our study reveals regional differences in activity popularity, especially with collecting mushrooms and berries, which are prevalent in Central-Eastern Europe but limited in Western Europe (Fig. 2c). This highlights cultural variations in forest use motivations across surveyed countries, showing how cultural nuances shape preferences and activities in forest environments. Regional activity differences in forests underscore the intricate influence of cultural norms, societal practices that may shape the links between people and nature, which is in line with the Nature's Contribution People conceptual framework[48]. Understanding these cultural nuances is essential for crafting sustainable forest management strategies and conservation efforts which. For example, in Poland, concerns about new conservation areas often stem from fears of restricted forest access and/or bans on mushroom and berry collection[49,50].

In most countries surveyed, the primary motivations for recent forest visits among the respondents were walking and appreciating nature (Fig. 2c). Remarkably, in all examined countries, except for Belarus, this inclination toward nature appreciation was chosen by over half of the respondents, nearly matching the frequency of walking itself. These results underscore that forests go beyond being mere walking spaces; they hold a crucial role in cultivating a connection between people and nature. These findings suggest a potential synergy between achieving conservation objectives and providing intangible benefits to visitors, highlighting the pivotal role of forests in fostering both ecological preservation and human well-being.

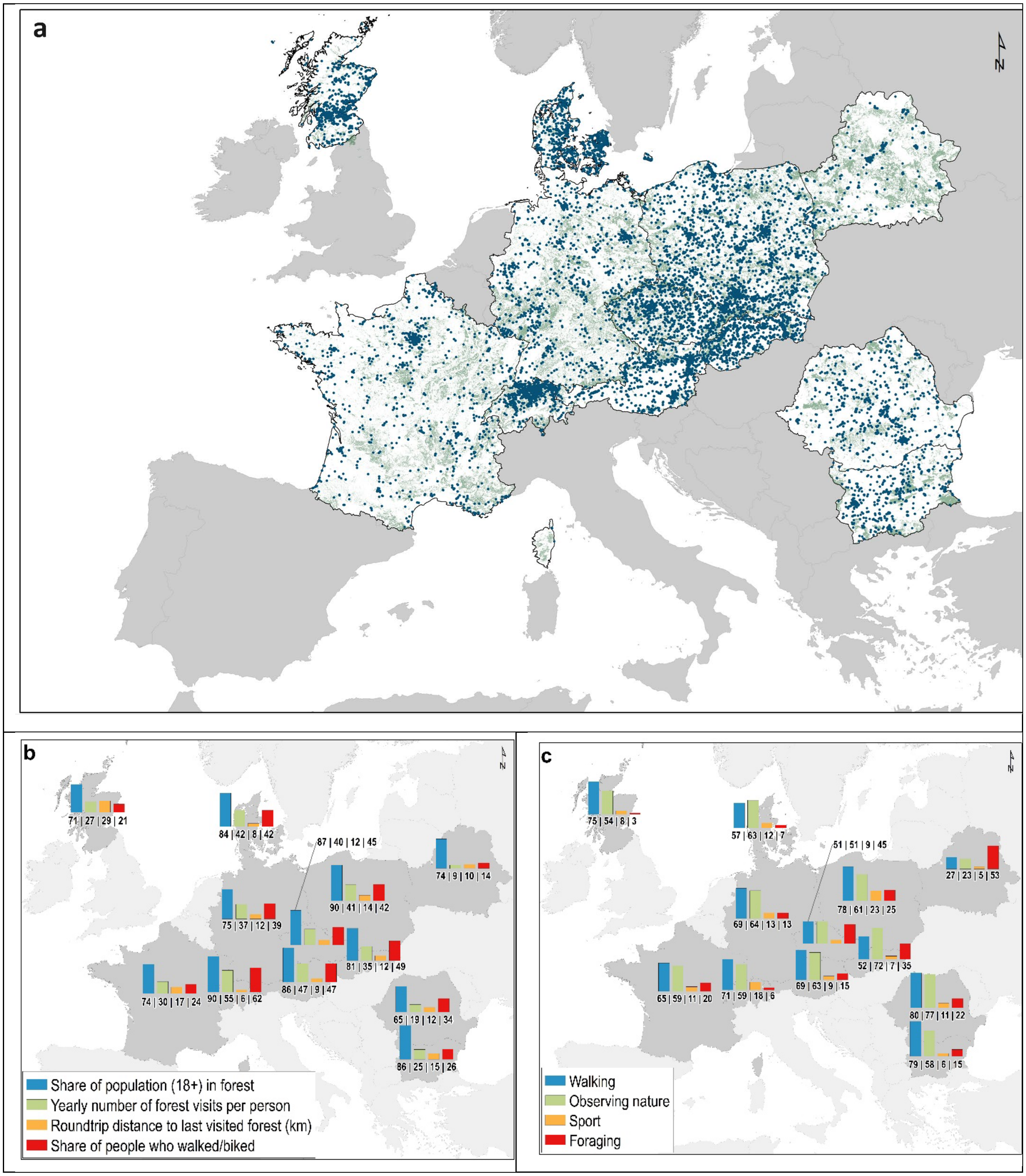


Fig. 2. **Recreational Use of Temperate Forests in Europe**. a) Geographic Distribution of Study Participants: Spanning 12 countries, with nationally representative samples ranging from N=863 to 1016 respondents per country, totalling 11,622 respondents. b) Overview of Forest Recreational Use: Summary statistics. c) Primary Motivations for Forest Visitation (multiple options were available).

Value and significance of recreation in forests

Recognizing the importance of ecosystem services for human well-being has sparked interdisciplinary debates on estimating their economic value[51–53], leading to two main approaches: welfare economics and accounting practices, emphasizing exchange value[54,55]. Due to the absence of observable market prices for forest recreation, the use of market price equivalents is recommended[54]. The travel cost is considered the closest proxy for valuing forest visits using the exchange value approach[54,56]. Since time is a scarce resource, welfare indicators account for the value of travel time alongside travel cost[46]. Therefore, CS was produced in two variants: with and without the value of time. In essence, we examined the recreational value from two different perspectives: accounting practice (incurred cost) and welfare economics (CS).

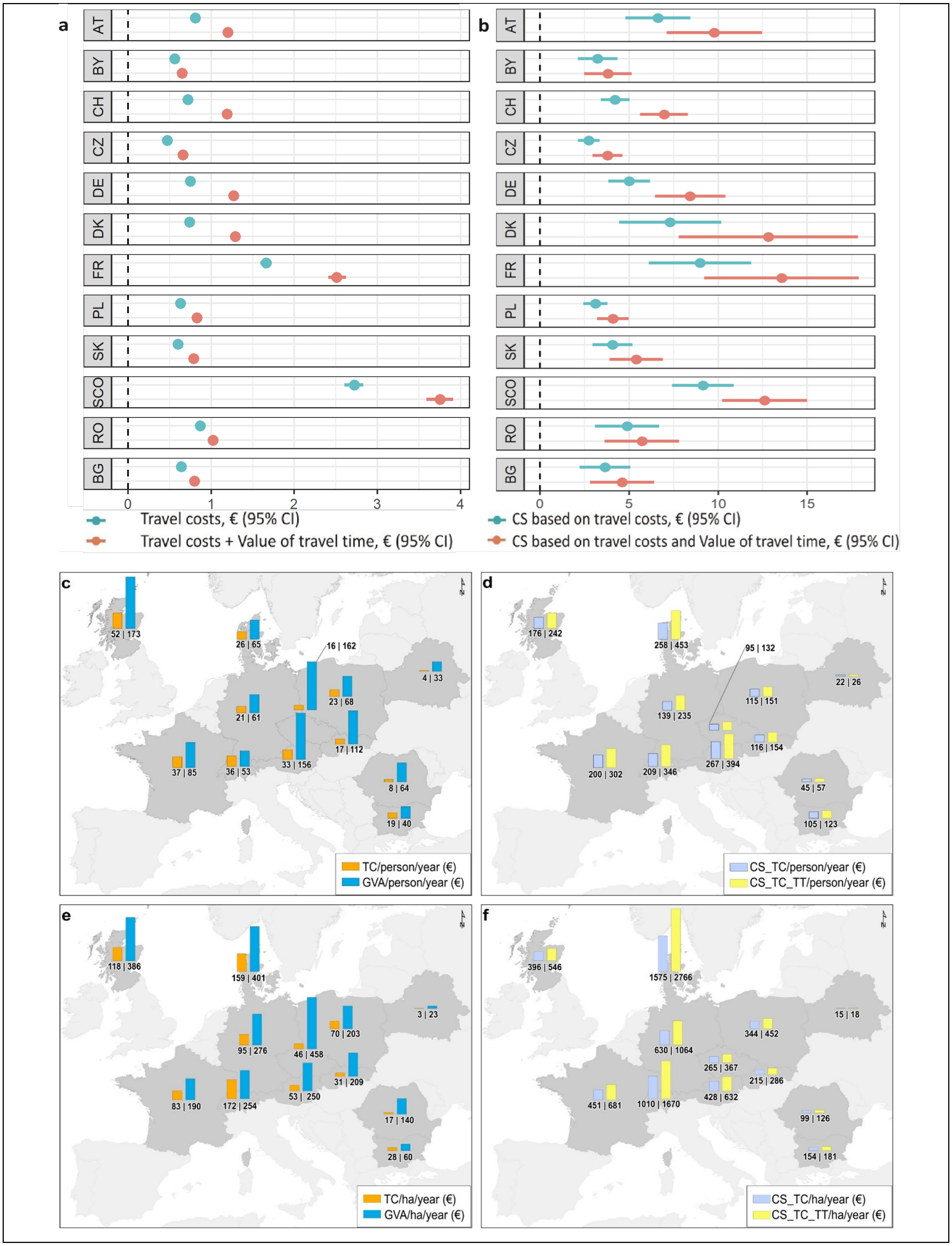
Figure 3 presents the indicators of recreational benefits provided by forests. They are expressed as: value/trip (Figure 3a-3b), value/person/year (Figure 3c-3d), and value/ha/year (Figure 3e-3f) in 2017 prices. When the recreational trips are evaluated at the incurred cost, the value varies from 0.47€/person/trip for Czechia to 2.72€/person/trip for Scotland (Figure 3a). This translates to benefits ranging from 4 to 52€/person/year (Figure 3c) or to 3-172 when expressed in €/ha/year (Figure 3e). Much higher values are noted when CS is used as an indicator of recreational benefits. In this case, the value varies between 2.7 in Czechia and 9.1€/person/trip for Scotland (Figure 3c). After including VTT into the travel cost, the CS ranges from 3.8€/person/trip in Belarus to 12.2€/trip/person for France (Figure 3d). This corresponds to the values ranging between 26€/person/year for Belarus to 453€/person/year for Denmark (Figure 3e).

For a comprehensive assessment of the extent of recreational benefits, we also offer a comparison between these benefits and the country-specific gross value-added of forestry[57] (GVA), considering that timber represents the most tangible marketed forest ecosystem service. When all forest visits, including walking and biking trips, are evaluated based on the cost of driving, which can be considered the most conservative approach, the ratio of recreational benefits to GVA ranges from 0.10 in Czechia to 0.68 in Switzerland (Figure 3c). The mean across the studied countries is 0.31, and this ratio becomes larger than GVA in most countries when recreational benefits are assessed using CS (Figure 3d).

Valuing recreational benefits is challenging due to the lack of market transactions, especially for forest visits on foot or by bicycle. Using car-based proxies for these trips results in low values due to their short distances. Switzerland illustrates this issue well. About 78% of all Swiss forest visits are on foot or by bike, indicating the proximity of forests that meet people’s expectations to residential areas.

However, valuing these trips based on actual incurred costs gives Switzerland one of the lowest recreational values per person among the studied countries, at 0.35€/person/trip (or 17€/person/year; see Supplementary Materials for detailed results). This increases to 0.72€/person/trip (or 36€/person/year) when using car travel costs as proxies for foot/bike trips (Figure 3a and 3c). Thus, a discrepancy arises: despite highest forest visit rates among the studied countries, Switzerland has relatively low recreational benefits due to the high share of walking/biking trips.

This example highlights that relying on car-based proxies is likely to undervalue walking/biking trips. A possible solution could be to evaluate all trips using the CS indicator, as there are no reasons why car trips for short visits should hold higher recreational value than walking/biking trips, especially given the negative externalities of car trips versus the positive benefits of walking/biking[58].



Note: AT: Austria; BY: Belarus; CH: Switzerland; CZ: Czechia; DE: Germany; DK: Denmark; FRA: France; PL: Poland; SK: Slovakia; SCO: Scotland; RO: Romania; BG: Bulgaria

Fig 3. **Country-specific indicators of recreational benefits provided by forests.** (a) Expressed as Travel Costs with and without Value of Travel Time per person/trip, (b) CS with and without Value of Travel Time per person/trip. (c) Travel Costs/person/year compared with gross value added generated by the forestry and logging industry (GVA/person/year), (d) CS with and without Value of Travel Time per person/year (e) Incurred travel cost and GVA per ha/year, (f) CS with and without Value of Travel Time per ha/year.

The significance of forest structures for recreational benefits

Given the substantial recreational benefits that forests provide, we directed our attention to better understand the link between forest attributes and the potential to provide recreational benefits. Preferences for all forest attributes are expressed in kilometres as WTT for DCE results, and in terms of additional forest visits due to changes in the forest structures in the regression analysis of revealed forest visitation behaviour. Both sets of results are summarized in Figure 4a and 4b.

Within the defined ranges, tree height has the highest impact on the recreational benefits. For this attribute we observe a strong positive relationship with WTT, suggesting that the presence of old, tall trees is a crucial factor attracting people to visit a forest. On average, individuals would be willing to travel an additional 39 kilometres (roundtrip) to visit a forest with 24-meter-tall trees, with a young forest composed of 8-meter trees serving as the baseline.

In terms of forest type, mixed forests with four tree species were the most preferred, with a WTT of 33 kilometres, with broadleaved monoculture as the baseline. When comparing forest types composed of the same number of species (green frame Fig. 4a-4b), mixed forests are preferred over broadleaved, which in turn are preferred over coniferous stands. Interestingly, this preference relationship between broadleaved and coniferous reverses when monocultures are compared. Within each forest type, forests with a larger number of tree species are considered more attractive. This underscores respondents' strong preferences for diversity.

The importance of tree layers and the presence of deadwood in the forest is found to be relatively lower compared to tree height, forest type and number of tree species. Nevertheless, within the studied ranges, forests with a greater number of tree layers and a higher abundance of deadwood are considered more attractive, with an increasing rate for tree layers and a decreasing rate for deadwood.

Overall, the results indicate statistically significant and strongly positive preferences for older stands with more complex forest structures. Despite substantial heterogeneity between countries, this positive pattern holds across the 12 studied nations (see the Supplementary Materials for detailed results).

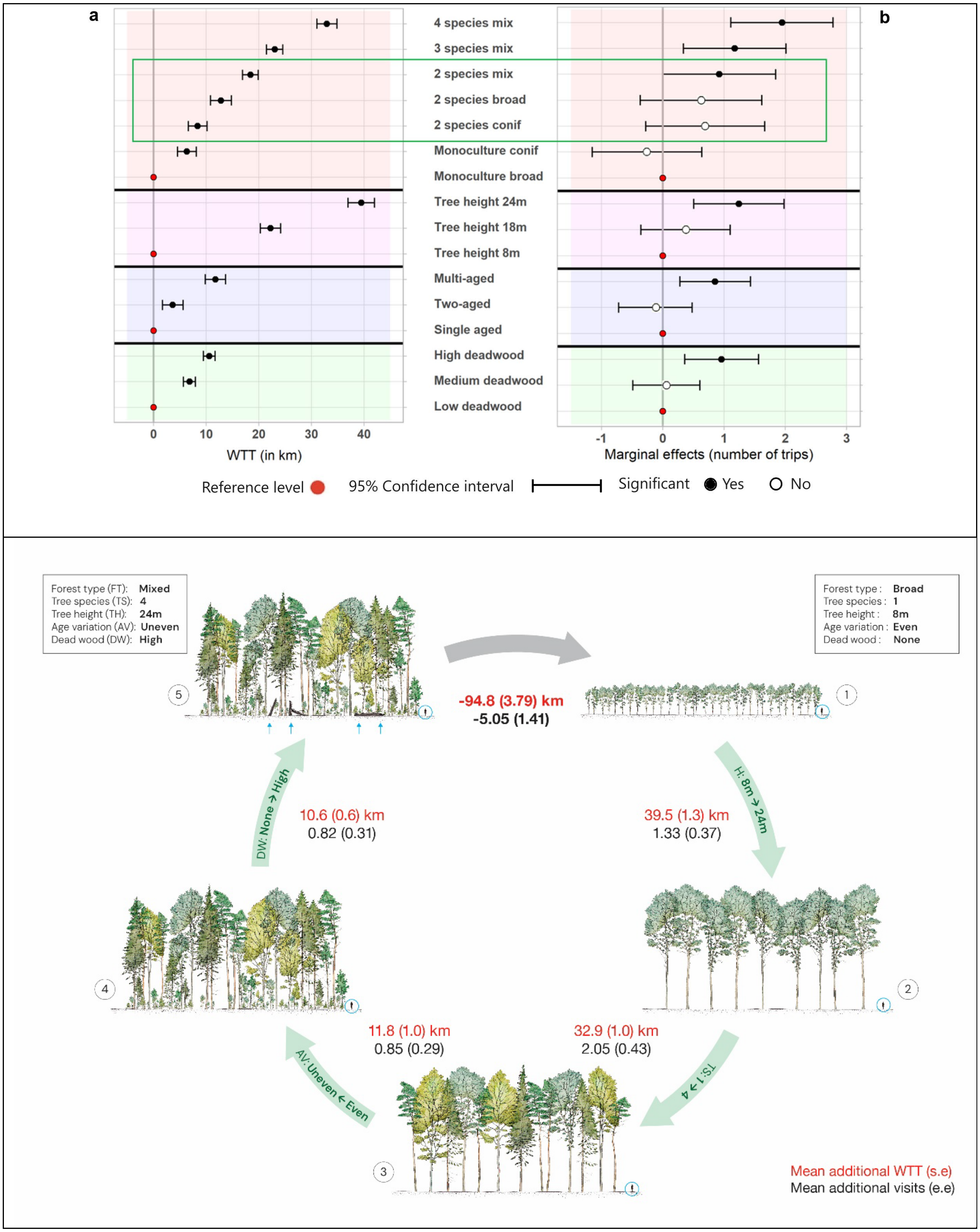


Fig 4. **Visitor Preferences for Forest Structural Attributes.** a) Estimated, within the discrete choice experiment framework, mean willingness to travel (in km) to visit a forest with a given level of forest characteristics relative to the reference level. b) Estimated marginal effects (additional forest visits) based on a count data model relating the

number of forest visits to forest characteristics. c) Changes in WTT and in Marginal Additional Visits resulting from changes in Tree height (1→2), Tree species composition (2→3), Age variation (3→4), Presence of dead wood (4→5) and replacing complex forest structure by simplified, homogenous forest in the growing phase (5→1).

We also investigated the impact of forest complexity on annual visitation frequency, with the use of perceived forest characteristics of the last visited forest. To ensure comparability with the DCE, the same specification for forest characteristics was used. Here, we focus solely on forest characteristics and the number of visits made by individuals (see the Supplementary Materials for full results).

In terms of direction, the forest characteristics have a similar impact on the number of visits as on WTT. Specifically, people declared to visit forests with more complex forest structures more often. Results imply a greater number of visits to mixed forests compared to broad-leaved monocultures, which served as the baseline. For example, mixed forests consisting of four tree species are associated with an average increase of 1.94 visits/person/year compared to broadleaved monoculture forests. Moreover, forests composed mainly of older trees (24m) were visited 1.24 times more per person/year than forests with predominantly younger trees (8m).

This pattern extends to the number of tree layers and the presence of deadwood. Forests were reported to be visited more frequently if there were more tree layers and if deadwood was present, with respective increases of 0.85 and 0.95 visits/person/year compared to the corresponding baselines. These findings highlight that forest quality not only impacts the benefits derived from a single trip, but also influences the overall number of trips people make, which links to health as exposure to nature plays a positive role in providing positive health outcomes[6,8,15,16].

One of the most controversial issues in the management of multifunctional forests around the world has been the simplification of forest structure and composition as a part of intensive wood production[59,60]. The type and intensity of disturbances that occur under industrial forestry can deviate dramatically from those of natural disturbance processes[24]. Figure 4c illustrates the changes in WTT and the additional number of forest visits as the forest structures transition from a simplified plantation-like state to a highly structured, complex phase resembling a close-to-natural stand. This phase features multiple tree layers, diverse tree species, and the retention of dead wood for natural decay. Additionally, we demonstrate the resulting change in WTT and the number of forest visits due to the homogeneous stand resulting from intensive management.

Direct assessment of the preferences for the forest structural characteristics

To validate the preference study results, we directly evaluated forest characteristic preferences in a subset of countries. Participants in Bulgaria, Poland, and Romania apart from completing the standard questionnaire, were asked to indicate their most and least preferred levels for each forest characteristic. This process generated a comprehensive preference ranking, as depicted in Figure 5. The findings show a significant qualitative correspondence with preference estimates derived from the DCE and regression analysis, confirming the consistent preference for more intricate forest structures.

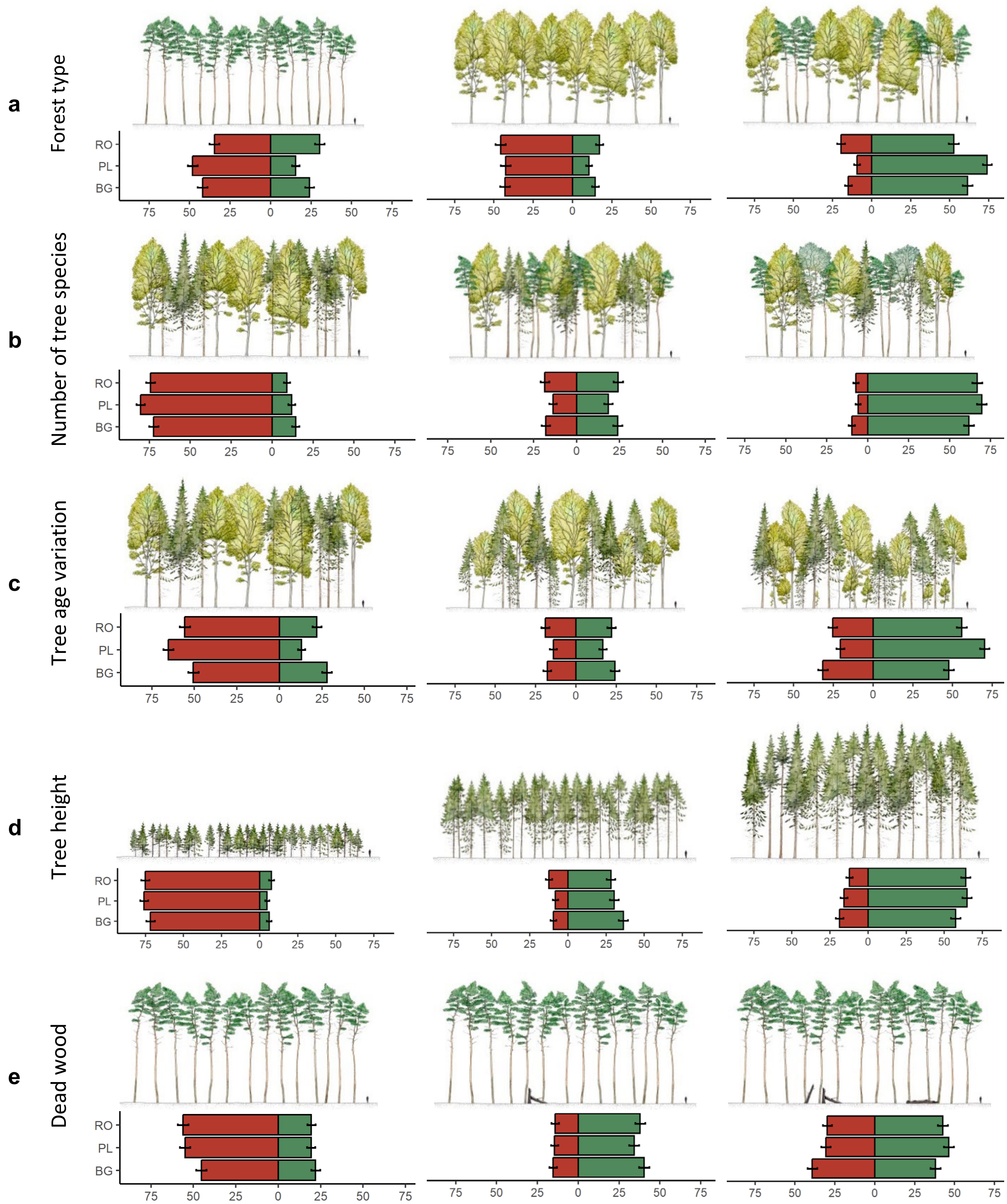


Fig 5. **Validation of preferences for forest structural characteristics in Bulgaria (N=960), Poland (N=1001) and Romania (968).** In green/red the share of respondents who perceived a given level as the most/least attractive. (a) Forest type (b) Number of tree species (c) Tree age variation (d) Tree height (e) Dead wood.

Policy implications

Europe's forests are presently undergoing a transition due to the direct and indirect effects of climate change, resulting in significant impacts on forest cover, species composition, and productivity[61–63]. These environmental challenges require adjustments in forest management to achieve targets for climate change mitigation and adaptation, as well as biodiversity conservation[64–66]. To support these objectives, the EU is proposing various strategies and policies, including a roadmap to plant at least three billion additional trees in the EU by 2030[67].

Forests already cover over 40% of Europe's total land area[68]. Despite an increase in forest cover over recent decades, forest-related conflicts persist and are aggravating[69–71]. These conflicts primarily arise from the clash between increased societal demand for recreation and the need to conserve forests of high natural value, juxtaposed with intensive forestry operations[70], indicating that forest-related conflicts are more about forest quality than quantity. Furthermore, forest management is faced with the challenges of climate change, leading to a higher intensity and frequency of large-scale forest damages with impact on forest functions and services[63,72,73]. Thus, European and national policies should better reflect these aspects in their strategies by going beyond top-down prescriptive initiatives and proactively fostering bottom-up best practice approaches.

Our study offers valuable insights into this matter. Forest recreation is widely popular across the studied countries and provides substantial recreational benefits, with nature-oriented motives ranking among the most prevalent reasons for forest visits. Our findings highlight the significance of a forest's condition, not only as a habitat for biodiversity but also for human recreation. Forests with more complex structures provide higher recreational value and attract more visitors. Consequently, intensified forestry operations resulting in younger, more homogeneous stands negatively impact visitation rates and the benefits derived from forest experiences. Conversely, managing forests to enhance biodiversity is likely to yield potential synergies with the provision of CES, as ecosystems with diverse structural components, which are more attractive to people, typically support greater biodiversity[20-25].

Managing forests to optimize multiple objectives simultaneously is challenging, often leading to trade-offs and conflicts among different functions[69]. Various management regimes yield distinct forest structures, which in turn influence the provision of ecosystem services[74]. Our study contributes by offering quantifiable indicators that correlate with ecological structures, aiding forest management and conservation planning. By identifying these indicators, managers can better understand how different management approaches affect ecosystem services and make more informed decisions to balance conflicting objectives[75].

It's important to also recognize the limitations of our study. We acknowledge that our use of schematic graphics aids in visualizing forest stands but may oversimplify real-world complexity. Moreover, we note the inherent limitations of SP methods, which may suffer from hypothetical bias[76]. However, these limitations should not compromise the documented relative importance of forest attributes in providing CES. Overall, our study contributes to the growing body of knowledge emphasizing forests' pivotal role in enhancing human well-being. It advocates evidence-based approaches in forest management and underscores the necessity for coordinated measures aimed at improving European forest quality.

Methods

The results presented in this article are based on the findings of an online survey that we designed and distributed to explore visitors' recreation behaviour in forests and preferences for forest characteristics in 12 European countries with temperate forests. Below, we describe the process of data collection, the survey instrument, the data preparation and analysis.

Data collection

The survey was administered online to a representative sample of adult individuals from the general public across 12 European countries. Renowned market research companies were engaged to recruit participants through online panels within each country. Voluntary participation was emphasized, and respondents were informed of their right to withdraw from the survey at any point. Quota-based sampling methods were employed in all countries to ensure two criteria: a) participants had made at least one forest visit within the 12 months preceding the survey, and b) the sample reflected the demographic composition of each country's population, including gender, age, settlement size, education level, and regional distribution. A copy of the questionnaire is available in the Supplementary Materials.

Data collection took place in 2017 (Austria, Czechia, Denmark, France, Germany, Scotland, Slovakia, and Switzerland), and in 2022 (Bulgaria, Poland and Romania), following extensive pre-testing and piloting procedures. The only discrepancy between the 2017 survey and subsequent versions was the inclusion, in later iterations, of questions asking respondents to specify their most and least preferred levels in addition to perceived forest characteristics.

The online implementation of all national questionnaires was facilitated through a server owned by Kantar Millward Brown in Warsaw, Poland, ensuring consistent data collection procedures across all countries. The survey adhered to the ethical standards set forth by the participating universities. Detailed information on sample sizes by country can be found in the Supplementary Information.

Modelling TCM data

To calculate the aggregate annual recreational benefits, two key estimations were conducted. First, we estimated the average benefits per forest visit in terms of consumer surplus (Figure 3b). Second, we utilized information on the total number of forest visits made by the population of each country over a one-year period. This was done using the answers to the question about the frequency of forest visits (Q48 in the questionnaire).

To determine the average value per trip, we assumed that data on the last visited forests from the sample were representative of annual forest use. To avoid confounding recreational benefits with other benefits we focused solely on one-day, single-purpose forest visits providing a conservative estimate of forest recreational benefits. As part of the questionnaire respondents were also asked to identify the forest, they visited on Google Maps and report the name of the nearest village, town, or city (Q9 in the questionnaire). Additionally, they were asked to provide the zip code of their place of residence and, if the start of the trip was different from their place of residence, to mark the starting point of the trip on Google Maps. This information, combined with the answers to the question about the exact distance travelled, enabled a validity check to ensure the accuracy of the reported locations and allowed for a consistent calculation of the distance travelled for all respondents. After cleaning the implausible observations, we employed the individual travel cost method to estimate the average value per trip. The socio-demographics and the country sample sizes are reported in Supplementary Materials, Table S2.

The probability of an individual taking a trip (*y*) to a specific site (*n*) was estimated using the truncated negative binomial model[77]. This model accommodates overdispersion and truncation at zero[77]. The probability is expressed as:

$$Pr(y_n | X_n) = y_n \frac{\Gamma\left(y_n + \alpha_n^{-1}\right)}{\Gamma(y_n + 1)\Gamma\left(\alpha_n^{-1}\right)} (\alpha_n \lambda_n)^{y_n} \left(1 + \alpha_n \lambda_n\right)^{-\left(y_n + \alpha_n^{-1}\right)}, \quad y_n = 1,2,... \qquad [1]$$

In Equation (1), y represents the number of trips, X denotes a vector of explanatory variables, including the cost of travel. The error term is assumed to follow a gamma distribution. The distribution in equation (1) has conditional mean λ_n and conditional variance $\lambda_n\left(1 + \alpha_n \lambda_n\right)$. Since λ_n >0 and $\alpha_n > 0$ the variance is greater than the mean. Additional explanatory variables included in the model were age, gender, municipality size, education level, a binary indicator for weekend trips, and the proportion of forests within a 10 km buffer around the respondent's place of residence to control for available substitutes. The data for each country were analysed independently, and the resulting parameter for the cost variable was used to calculate country-specific consumer surplus (CS) for an average forest trip. The full modelling results are reported in the Supplementary Materials in Sections 3 and 4.

Exploring the link between forest characteristics and number of visits

In addition to the country-specific TCM models used to calculate CS, we estimated a joint negative binomial model encompassing all countries to examine the impact of perceived forest characteristics on the number of trips taken. The joint model incorporated socio-demographic variables, characteristics of the respondents' residential areas (municipality size, proportion of forest and water within a 10km buffer), perceived forest characteristics (forest type, number of tree species, height, number of tree layers, presence of deadwood, presence of tourist infrastructure), trip characteristics (motive of the trip, mode of transport, weekday trips vs. weekend/holiday trips), and country-specific indicators. All forest attributes were dummy coded to ensure comparability with the Discrete Choice Experiment results. Model estimates were utilized to calculate marginal effects (additional visits due to changes in forest characteristics), with standard errors derived using the Delta Method[78]. In the main text, our focus was on investigating the association between forest characteristics and the number of visits made by individuals, while complete results can be found in the Supplementary Materials in Section 2.

Consumer Surplus

Consumer surplus per person per trip was an indicator which was used to calculate country specific recreational benefits provided by forests. CS value per person per trip was calculated using the formula: $-1/\beta_c$, where β_c is the TC coefficient. The standard errors were obtained using the Delta Method[78].

To ensure the isolation of recreational benefits from other unrelated activities undertaken during the trips, our analysis excluded multipurpose trips and those lasting longer than one day. Individual travel cost per trip was calculated by summing travel-related expenditures ("travel cost": TC), which encompassed the cost of fuel, tires, maintenance and repairs, insurance, and average vehicle depreciation[79], and the opportunity cost of time ("value of travel time": VTT) in the variant of TCM with VTT. Travel distance was determined using Google Maps. For respondents who travelled by car, the estimated travel distance was subsequently utilized to calculate trip expenditure to the forest. We assumed on average two persons sharing the full cost of driving, so the TC variable used in estimation was divided by two.

In the variant with VTT the calculated travel distance was also employed to derive trip duration for VTT calculations. For this purpose, an average travel speed of 50 km/h was assumed. Given the considerable proportion of respondents who declined to disclose their personal income during the survey, we assumed the VTT to be equivalent to 1/3 of the hourly wage rates specific to each country. Wage rates were obtained from OECD statistics for all countries included in our study[80].

The national-level recreational benefits were calculated by multiplying the average per-trip consumer surplus (CS) by the total number of forest trips. To ensure better comparability between countries, these benefits were expressed as values per citizen (Fig. 3d) or per forest hectare (Fig. 3f). The total number of forest trips per country was obtained by multiplying the average number of annual forest visits per person by the population aged 18 and above, adjusted by the proportion of the sample who reported visiting a forest in the previous year.

Value of recreation in forests, national accounts

Consumer surplus is typically used in monetary valuation where the objective is to estimate changes in the provision of services, while exchange values are estimated when the values are to be used in national ecosystem accounts. As forest recreation is a non-market service, no market price (exchange value) can be observed. It has been suggested that the exchange value of recreational visits can be estimated by simulating hypothetical markets[54,81]. However, the simulation of markets requires assumptions about the market structure, e.g. in a study of the accounting value of inland swimming sites in Finland[82] it is assumed that hypothetical competing providers of recreation visits have market power over swimmers living nearby. We estimate an approximation of exchange values assuming perfect markets, i.e. the exchange value is equal to the travel cost. It can be argued that hypothetical suppliers of forest recreation visits have little market power due to the relatively large number of local forest sites from which a visitor can choose. Our assumption implies that the estimated 'exchange value' is a minimum value. When market prices are not observable, as is the case with recreation, valuation based on market price equivalents should be used to provide an approximation of market prices[54]. Therefore, the travel cost was assumed the most suitable proxy to estimate the exchange value of forests’ visits.

It is important to note that although consumer surplus is not congruent with national accounting, it serves as a theoretically valid measure of welfare, indicating that changes in its value represent changes in consumer welfare associated with the respective good or service[83]. Furthermore, under certain market structures, consumer surplus is equivalent to exchange value[83].

Data and approach to valuing the benefits of forest structural characteristics using DCEs

For the design of the DCE, main forest structural attributes and their relevant levels had to be identified on a management-intensity gradient from less to more natural forests. The landscape and forestry literature provides a long list of potential attributes. In our study, we operationalized the most important forest characteristics, as identified in other forest preference studies[44,45]. The relevance of these forest characteristics was confirmed in numerous pre-tests in all the countries considered in our study and focus groups in Denmark and Poland. The attributes are:

Tree height – the height of the upper tree storey in the forest. Levels: 8m; 18m; 24m. To visualise the scale of the trees an icon of an average-sized person was added to each visualisation.

Forest layer – variation in the structure of the forest. Levels: Single: forest composed of a single layer (age class); Two: forest with trees of two layers; Multiple: forest with multiple layers.

Number of tree species and forest type – refers to the number of tree species within a stand. Levels: 1 and 2 tree species for broadleaved and coniferous forests and 2, 3, 4 for mixed forest. Graphics of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) were employed to visualize coniferous species, oak (*Quercus robur*) and beech (*Fagus sylvatica*) to visualize broadleaved tree species.

Deadwood – this attribute refers to the amount of natural deadwood (standing and fallen) in the forest. Levels: Low; Medium; High. Respondents were informed that this attribute refers to large pieces of natural deadwood to avoid confusion with the presence of residuals from harvesting and thinning.

Visitor infrastructure – this attribute refers to the presence of infrastructure for visitors in the forest. Levels: None; Picnic sites; Trails; Picnic sites & trails. As this attribute is unrelated to the topic of this paper – forest structures – results for it are only reported in Figure S5. in the Supplementary Materials.

Distance to forest – refers to the distance to the forest from an individual's home (or any other location where the trip to the forest would start). To maintain realism, the levels of distances used in the DCE were pivoted based on the distance reported by a respondent for their last visit (answers to Q25). We used five different sets of distances depending on the answers to Q25, with six levels in each set (Supplementary Materials, Table S3).

Substantial effort was devoted to adequately explaining the forest characteristics. A novel approach of our study is that respondents learned about the DCE attributes by defining the structural forest characteristics of the last visited forest during the survey, using visual aids to indicate the attribute levels that were perceived to best match the last visited forest. The resulting forest was visualized and included as a third alternative in the choice tasks (see questions Q37-Q41). After completing the matching exercise with all attributes, an illustration of a forest profile combining all attributes was instantly generated and shown on the screen. Respondents were asked (on a scale 0-100) to rate how well the generated illustrations resemble the perception of the forest they had visited. Responses are consistent across the countries and relatively high with an average score ranging from 71 for Slovakia to 79 for Romania (Table S4 in the Supplementary Materials).

The D-efficient experimental design (with the status quo as zero) consisted of 36 choice sets divided into 3 blocks, each containing 12 choice cards. This design was generated using NGENE software[84]. The example of the choice card can be seen in the Supplementary Materials (Figure S1). The design for the main survey was generated using priors obtained from the pilot experiment. The final design was optimized for median Bayesian D-error of the MNL[85] model based on data from a total of 900 pilot interviews. Across respondents, we randomized the order of choice tasks presented to counter-balance possible ordering and anchoring effects. The same experimental design was applied in all 12 countries.

Since the focus in the TCM part was on estimating the country-specific value (CS) per average forest trip, a detailed validity check regarding the start and end of the trip and the reported travelled distance was conducted, resulting in the screening out of some observations. In the DCE section, to avoid confounding recreational benefits with other benefits, we only screened out multi-purpose trips. All other observations were retained in the sample. Therefore, the sample sizes used in these two parts are different (Supplementary Materials, Table S2).

The choices recorded enabled us to estimate the marginal rate of substitution (MRS) between having a forest characteristic present in the forest and travel distance. The trade-offs between forest characteristics and distance indicate the relative value of forest characteristics in terms of Willingness to Travel (WTT). WTT represents the number of additional kilometres that a person would be willing to travel to visit a forest with the characteristic of interest (relative to a baseline level), all else equal. We derive

WTT estimates directly from the coefficients of a mixed logit model estimated in WTP space with correlated random parameters (full covariance matrix). The unconditional choice probability in the Mixed Logit takes the form[86]:

$$P_{ni} = \int \frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}} \varphi(\beta | b, \Omega) d\beta, \quad (2)$$

where: $\frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}}$ is a standard MNL formula, $\varphi(\beta | b, \Omega)$ is the density of the random coefficients with mean *b* and covariance *Ω*. Since we are interested in marginal Willingness to Travel (WTT), it is convenient to estimate parameters directly in WTP space[86] which in our case is WTT space as cost is replaced with distance. That is: $U_{njt} = \alpha\left(p_{njt} + \boldsymbol{Y}_{njt}\boldsymbol{b}\right) + e_{njt} = \alpha\left(p_{njt} + \boldsymbol{Y}_{njt}\boldsymbol{\beta}\right) + e_{njt}$.

In this specification the vector of parameters $\boldsymbol{\beta} = \boldsymbol{b}/\alpha$ can be directly interpreted as a vector of implicit distances for forest structural characteristics $Y_{jnt.}$ All distributions, except for distance to the forest were assumed to be normal. The distance coefficient was assumed to follow log-normal distribution. This is equivalent to impose the economic theory-driven restriction that marginal utility of money (in our exercise we assumed that respondents paid with travelled distance) is expected to be positive for all respondents.

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