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Explaining forest value perceptions across Europe: A multilevel analysis of individual and geographic variation

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ABSTRACT

Understanding how forest values vary across individuals and geographic contexts is important for comparative forest research and governance. We examined socio-cultural, provisioning, and regulating/supporting forest values among 12,460 adults in 12 European countries and five macro-regions. Weighted linear mixed-effects models estimated associations with socio-demographic characteristics, forest ownership, and social proximity to forest owners, while three-level models partitioned residual variation across macro-regions, countries, and respondents. Most residual variation occurred at the respondent level, but geographic clustering differed across value domains. Country and macro-region jointly accounted for 21.22% (95% CI [8.08, 37.90]) of residual variation in provisioning values, compared with 2.19% [0.65, 4.58] for socio-cultural and 2.60% [0.87, 5.38] for regulating/supporting values. Despite descriptive geographic differences, no adjusted macro-regional contrast had a 95% confidence interval excluding zero. In the primary models, older age groups had higher values across all domains, although provisioning-age associations weakened in the restricted-sample analysis. Gender and education associations varied by domain. Forest owners reported higher provisioning but lower socio-cultural and regulating/supporting values; the socio-cultural ownership association also weakened after sample restriction. Social proximity to forest owners was positively associated with all three domains. These findings highlight domain-specific geographic and social structuring of forest values, supporting approaches that distinguish forest-value domains while accounting for national context and within-country heterogeneity.

1. Introduction

European forests provide multiple ecological, economic, and socio-cultural benefits, ranging from wood and other material products to biodiversity conservation, climate regulation, recreation, and other contributions to human well-being (Brockerhoff et al., 2017; Winkel et al., 2022). At the same time, societal expectations of forests differ across places and stakeholder groups, creating challenges for balancing competing functions and interests within multifunctional forest landscapes (Angelstam et al., 2026; Dawson and Angelstam, 2026). These challenges are becoming increasingly important as climate change, biodiversity loss, and changing societal demands place additional pressures on European forests and their governance (Forest Europe, 2026; Sorge et al., 2026). Understanding how people value different forest functions, and how these values vary across individuals and geographic contexts, is therefore important for socially responsive and adaptive forest governance.

Previous research documents cross-national and social variation in forest perceptions, preferences, and uses across Europe. Comparative studies have examined public forest values and management attitudes (Eriksson et al., 2015), private forest owners' conceptualisations of forest management (Feliciano et al., 2017), and public perceptions of forest ecosystem services across countries (Ranacher et al., 2017). Pan-European surveys also document geographic and socio-economic differences in non-wood forest product collection and consumption, including among recreational, hobby, and professional collectors (Lovrić et al., 2021). A recent EU-wide study records differences across countries and between personal and societal perspectives in the importance attached to forest ecosystem services (Stratton et al., 2026). However, observed differences between national or regional samples may reflect contextual clustering, differences in population composition (that is, differences in the characteristics of the individuals comprising those populations; see Diez Roux, 2002), or both. Descriptive comparisons alone cannot determine how much each source contributes to

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geographic variation.

At the same time, studies in environmental sociology and ecosystem-service perception demonstrate that socio-demographic characteristics, including age, gender, and education, are associated with environmental attitudes and value orientations (Dietz et al., 2005; Franzen and Vogl, 2013; Thiemann et al., 2022). Forest-perception studies similarly indicate that age, education, forest ownership, and other forest-related experiences can differentiate how people evaluate forests and their functions (Eriksson et al., 2015; Hegetschweiler et al., 2022; Roitsch et al., 2026).

However, individual-level characteristics such as age, gender, education, and ownership status are commonly examined within national studies (Häyrinen et al., 2015; Mohammadi et al., 2025; Upton et al., 2015), while comparative research documents variation in forest perceptions across countries, regions, stakeholder groups, and institutional contexts (Eriksson et al., 2015; Hoang et al., 2026; Lovrić et al., 2020; Pezdevšek Malovrh et al., 2026). Relatively few studies integrate these dimensions by quantifying the extent of variation clustered at country or broader regional levels while simultaneously estimating individual-level associations.

This leaves an important empirical gap. It remains uncertain whether different dimensions of forest value exhibit similar geographic structuring. This is particularly relevant in Europe, where forest management conditions, ownership structures, and societal demands for ecosystem services vary substantially (Winkel et al., 2022). Provisioning values, which are more directly connected to material forest use, ownership, and economic activity, may therefore exhibit stronger contextual differentiation than socio-cultural or regulating/supporting values.

Forest-perception research encompasses descriptive comparisons, single-country studies, preference models, and approaches for identifying heterogeneity in perceptions and preferences. For example, Malkamäki et al. (2022) used network analysis to examine the multidimensional structure of public perceptions of the forest bioeconomy and identify groups of like-minded respondents. Bayne and Grant (2024) used cluster analysis to identify public segments with differing attitudes toward planted-forest practices, while Mäntymaa et al. (2023) used latent-class models to identify groups with differing preferences for forest-policy goals. Although these approaches characterise patterns or groups in perceptions and preferences, variance partitioning estimates the share of residual variation associated with nested geographic levels.

This study addresses this gap using a cross-national survey of 12,460 respondents from 12 European countries spanning the five Forest Europe macro-regions (Forest Europe, 2026). It examines three analytically distinct forest-value domains: socio-cultural values (recreation and experiential appreciation), provisioning values (material goods and products), and regulating/supporting values (biodiversity and environmental functions). Weighted multilevel models describe variation in each domain across countries and macro-regions, estimate associations with individual characteristics, and partition residual variation across these geographic levels.

The study is guided by three research questions (RQ):

RQ1. How do socio-cultural, provisioning, and regulating/supporting forest values vary across European countries and macro-regions?

RQ2. To what extent does variation in each forest-value domain cluster at country and macro-regional levels after accounting for individual characteristics?

RQ3. Which socio-demographic characteristics, forest ownership, and social proximity to forest owners are associated with socio-cultural, provisioning, and regulating/supporting forest values, and how consistent are these associations across domains?

The study contributes to comparative forest-perception research by clarifying whether geographic clustering differs across the three domains and how it relates to adjusted macro-regional contrasts.

2. Conceptual and theoretical framework

2.1. Ecosystem functions, ecosystem services, and forest values

Ecosystem functions refer to the ecological mechanisms that support the functioning and maintenance of ecosystems, whereas ecosystem services refer to the contributions ecosystems make to human well-being (Brockerhoff et al., 2017). The Millennium Ecosystem Assessment (MEA, 2005) classifies ecosystem services into cultural, provisioning, regulating, and supporting services. In this study, forest values refer to the importance respondents attach to forest-related benefits and functions captured by the survey. Accordingly, the three empirical domains examined here comprise socio-cultural, provisioning, and regulating/supporting values. Although these domains provide an analytically useful distinction among different dimensions of forest value, environmental sociology and value theory suggest that they are socially embedded within broader value orientations and life-course processes and may be structured by overlapping demographic and experiential factors rather than independent social logics (Dietz et al., 2005; Schwartz, 1992; Stern et al., 1999). Recent forest ecosystem-service research further shows that different services are not necessarily perceived or valued uniformly across societal groups or geographic contexts, reinforcing the need to analyse value domains separately rather than treating forest value as a single construct (Dehghani Pour et al., 2023). Understanding whether forest-value domains are socially structured in similar or distinct ways requires moving beyond descriptive categorisation toward theoretically grounded analysis.

2.2. Individual-level structuring of environmental values

Environmental sociology and value theory suggest that environmental orientations are socially structured rather than randomly distributed. Schwartz (1992) and Stern et al. (1999) show that environmental concern is embedded within broader value systems, including biospheric and altruistic orientations. Socio-demographic characteristics may also differentiate environmental orientations while operating alongside underlying values, beliefs, and normative commitments (Dietz et al., 2005; Stern and Dietz, 2008).

European research on forest perceptions and ecosystem-service values similarly shows that individual characteristics are associated with how people evaluate forests and their functions. Age, gender, and education have been associated with differences in ecological, cultural, recreational, and other forest-related values, although the direction and magnitude of these relationships vary across value domains and study contexts (Hegetschweiler et al., 2022; Janeczko et al., 2023; Roitsch et al., 2026; Thiemann et al., 2022).

Research among private forest owners indicates that their forest-related values and priorities are diverse rather than uniform. Ficko et al. (2019) reviewed private forest-owner typologies from 28 European countries and identified varied owner types, including recreationists, investors, conservationists, and multifunctional owners. Similarly, Tiebel et al. (2021) found that small-scale private forest owners placed greater importance on regulating and cultural services than on provisioning services and held a multifunctional perspective on their forests. They also reported differences in resource-use focus and nature-conservation attitudes between owners with and without Natura 2000 sites.

Together, this literature indicates that the associations of individual characteristics with forest values may differ across value domains. The present study examines how age, gender, education, residence duration, forest ownership, and social proximity to forest owners are associated with socio-cultural, provisioning, and regulating/supporting values.

2.3. Contextual versus compositional variation

Comparative environmental research frequently documents

differences in environmental attitudes across macro-level contexts, such as governance regimes, ecological gradients, or national cultures. However, distinguishing contextual clustering from differences in population composition requires explicit multilevel modelling. Cross-national research indicates that substantial variation in environmental orientations can occur among individuals within countries even where national differences are observable (Eriksson et al., 2015; Franzen and Vogl, 2013).

This distinction is especially important because fixed geographic contrasts and contextual variance answer different questions. A difference in the mean value of one macro-region relative to another does not by itself indicate that a large proportion of total variation is situated at the regional level. Conversely, contextual clustering may exist even when individual pairwise regional contrasts are estimated imprecisely. Multilevel variance partitioning therefore complements adjusted regional comparisons by quantifying the proportion of residual variation associated with country and macro-regional clustering.

By estimating intraclass correlations, the present study directly examines whether forest values cluster meaningfully at macro-regional or national levels, while the fixed-effect models estimate associations between forest values and individual socio-demographic characteristics, forest ownership, and social proximity to forest owners.

2.4. Hypotheses

Drawing on the above theoretical considerations, the study tests three hypotheses:

H1: After accounting for the included individual-level characteristics, residual variation in forest-value perceptions is greater among respondents within countries than between countries and macro-regions.

H2: Macro-regional differences in forest-value perceptions are reduced after accounting for individual socio-demographic characteristics, forest ownership, and social proximity to forest owners, conditional on country-level clustering.

H3: Contextual clustering at country and macro-regional levels is greater for provisioning values than for socio-cultural or regulating/supporting values.

3. Methods

3.1. Study area

This study covers 12 European countries: Croatia, Czechia, Denmark, France, Germany, Italy, the Netherlands, Romania, Scotland, Serbia, Spain, and Sweden (Fig. 1). Countries were selected a priori to capture variation in forest ecosystems and socio-cultural contexts of forest use across Europe, consistent with comparative forest policy and perception

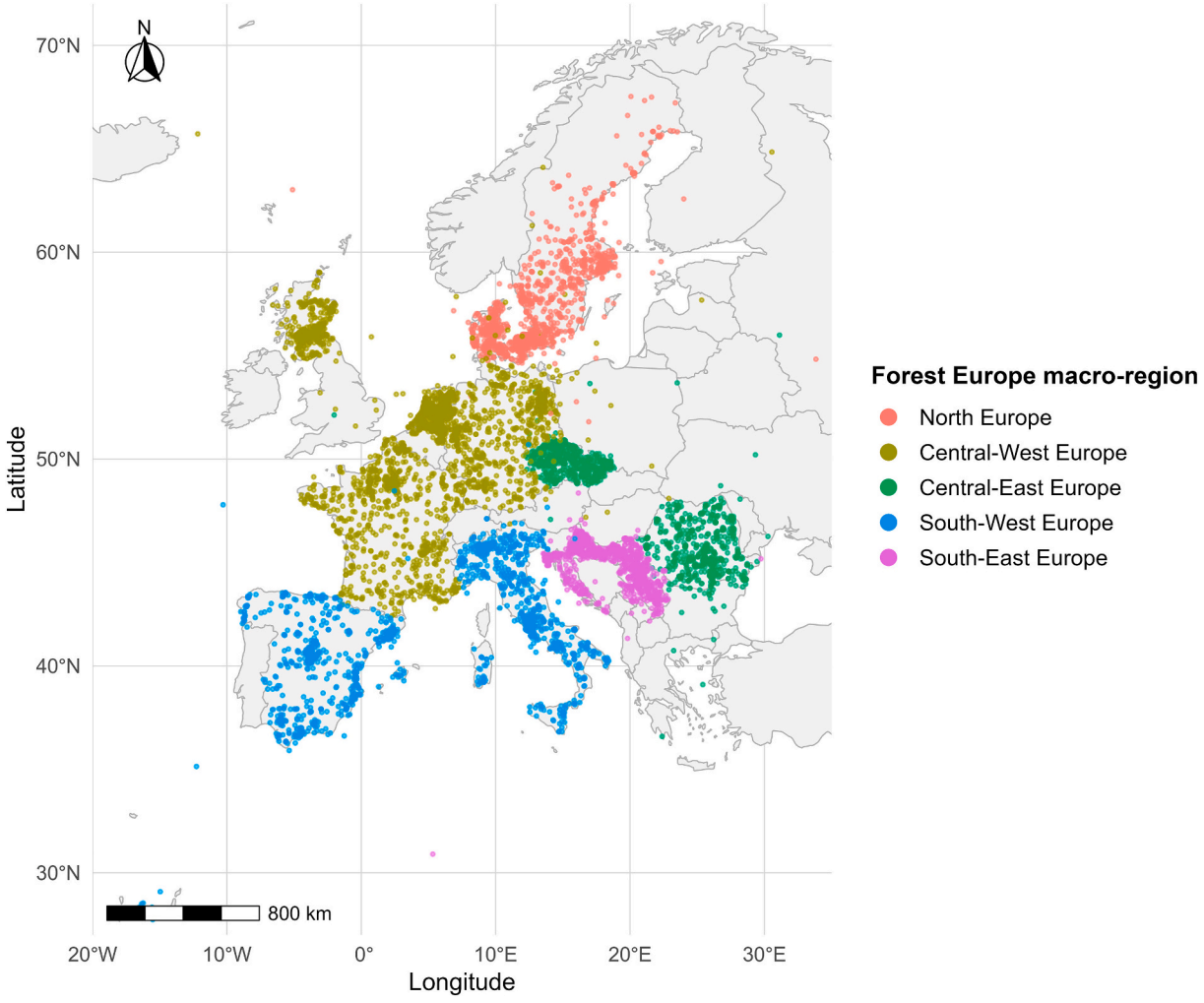


Fig. 1. Spatial distribution of survey respondents across the five Forest Europe macro-regions. Points indicate respondents with available geographic coordinates within the displayed study area. Colours denote the five Forest Europe macro-regions represented in the study: North Europe, Central-West Europe, Central-East Europe, South-West Europe, and South-East Europe. The analytical sample comprised 12,460 respondents across 12 European countries; 10,740 respondents with available coordinates within the displayed geographic extent are shown on the map.

research (Barbati et al., 2014; Nichiforel et al., 2020; Winkel et al., 2022).

For comparative analysis, countries were classified according to the five country groups used in the State of Europe's Forests 2025: North Europe, Central-West Europe, Central-East Europe, South-West Europe, and South-East Europe (Forest Europe, 2026). Within the study sample, North Europe comprised Denmark and Sweden; Central-West Europe comprised France, Germany, the Netherlands, and Scotland, with Scotland representing the United Kingdom classification in the Forest Europe country grouping; Central-East Europe comprised Czechia and Romania; South-West Europe comprised Italy and Spain; and South-East Europe comprised Croatia and Serbia. This established classification was used to define the macro-regional level in the comparative analyses.

3.2. Survey design, data collection, and sample

The survey instrument was developed following the sequential research framework outlined in Kazungu and Hunziker (2025) and Kazungu et al. (2025). It builds on earlier qualitative key-informant interviews conducted across multiple European regions (Kazungu and Hunziker, 2025), which explored societal perceptions of forests, ecosystem benefits, and restoration. Insights from this phase informed subsequent structured household surveys examining factors shaping forest-related perceptions. The refined and standardised questionnaire was subsequently adapted for multinational online panel implementation.

The present study draws on a subset of items from this broader survey programme. Specifically, it includes measures of socio-cultural, provisioning, and regulating/supporting forest values, together with socio-demographic characteristics including age, gender, education, length of residence, forest ownership, and social proximity to forest owners (Supplementary Material Table S1). Other components of the larger questionnaire are not analysed here.

Data were collected through a multinational online panel survey administered in 2024 by the opinion research company YouGov on behalf of the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. The survey was conducted between 22 August and 9 October 2024 in 12 European countries: Croatia, Czechia, Denmark, France, Germany, Italy, the Netherlands, Romania, Scotland, Serbia, Spain, and Sweden. The questionnaire required approximately 10–12 min to complete and targeted adults aged 18 years and older.

Respondents were recruited from YouGov's established online panels; in Serbia, a local panel partner was used to achieve national coverage. Online panels enabled standardised cross-national implementation while allowing demographic quota control.

Approximately 1000 respondents were surveyed per country. In Germany and Italy, additional geographically targeted samples were collected in North Rhine-Westphalia and the Milan area, respectively, for a separate comparison of public perceptions in areas located closer to restoration activities. These targeted oversamples were excluded from the present cross-national analysis because they were additional to the national panel samples and would have disproportionately represented these specific subnational areas within the German and Italian samples. The analysis was thus restricted to the national panel samples to maintain comparability of the sampling design across the 12 countries. Following data cleaning, 12 non-respondent artefact rows introduced during file import were removed, resulting in a final analytical dataset of 12,460 valid respondents.

3.2.1. Sampling and weighting procedures

Within each country, survey responses were weighted by the survey provider to improve alignment of the survey sample with the national adult population. Weighting was conducted using post-stratification (rim weighting) based on official population benchmarks specific to each country. Post-stratification weighting adjusts the contribution of respondents so that the weighted sample more closely reflects known population distributions and helps reduce potential bias arising from unequal selection probabilities, differences in sample composition, and differential non-response (Bollen et al., 2016; Valliant et al., 2013). Weighting variables varied by country but consistently included age and gender and, where available, region and additional socio-demographic characteristics such as education level, socio-economic status, or urban-rural residence.

Population targets were derived from authoritative national and international statistical sources, including national statistical offices and Eurostat. Detailed country-specific weighting targets and benchmark sources are documented in the survey provider's technical report. For the analyses reported here, respondent weights were normalised separately within each country by dividing each weight by the country-specific mean weight. Normalisation retained the relative differences among respondents within each country while giving the weights a mean of one within every country. The country-normalised weights were used for descriptive estimates and incorporated as prior weights in the linear mixed-effects models. This prevented differences in the scale of country-specific weights from disproportionately influencing pooled cross-national estimates and models. Because the treatment of weights in multilevel models can affect model estimates and inference (Bollen et al., 2016; Pfeffermann and Sverchkov, 2009), the primary models were also re-estimated without respondent weights as a sensitivity analysis.

Following removal of the 12 non-respondent artefact rows introduced during data import, the descriptive and primary multilevel analyses were based on the same analytical sample of 12,460 respondents.

3.2.2. Construction of forest value indices

Forest perceptions were measured using a series of statements rated on five-point Likert scales, ranging from 1, completely disagree, to 5, completely agree. Drawing on ecosystem service theory and prior literature, survey items were grouped a priori into three conceptual domains representing distinct dimensions of forest values (Supplementary Material Table S1).

Socio-cultural and experiential values were measured using four items capturing perceptions of forests as beautiful places, spaces for leisure and recreation, learning environments, and contributors to personal health and wellbeing (Q6, Q7a, Q8, and Q9; Supplementary Material Table S1). Provisioning values were measured using two items capturing perceptions of forests as sources of non-edible materials and edible or medicinal products (Q10a and Q11a). Regulating/supporting values were measured using three items capturing perceptions of forests as habitats for biodiversity, contributors to environmental quality, and providers of protection against natural hazards (Q12, Q13a, and Q14).

Composite indices were constructed for each respondent by averaging item scores within each domain, yielding continuous outcomes ranging from 1 to 5, with higher values indicating stronger endorsement of the respective forest-value dimension. The term “regulating/supporting values” is used to acknowledge that the domain combines perceived regulating functions with habitat- and biodiversity-related supporting functions represented by the survey items.

Internal consistency of the forest-value indices was assessed using Cronbach's α for all domains (Cronbach, 1951). McDonald's ω was additionally calculated for indices comprising three or more items (Dunn et al., 2014; McDonald, 2013). For the two-item provisioning domain, reliability was additionally evaluated using the Spearman-Brown coefficient (Brown, 1910; Spearman, 1910). The socio-cultural index showed good internal consistency (Cronbach's $\alpha = 0.79$; McDonald's $\omega = 0.80$). The provisioning index had a Cronbach's α of 0.74 and a Spearman-Brown coefficient of 0.74, while the regulating/supporting index had a Cronbach's α of 0.82 and McDonald's ω of 0.83 (Supplementary Material Table S2b).

3.2.3. Individual-level predictors

Individual-level predictors included age group, gender, educational

attainment, length of residence in the local area, forest ownership, and social proximity to forest owners. These variables were selected based on prior evidence linking socio-demographic characteristics to forest perceptions and use (Hegetschweiler et al., 2022; Mensah et al., 2017; Thiemann et al., 2022; Zoeller et al., 2021).

Gender was harmonised across country datasets and coded as male (reference) and female. Age was classified as 18–26 years (reference), 27–37 years, 38–48 years, 49–59 years, and ≥ 60 years. Educational attainment was harmonised into six ordered categories: Level 1 (no formal education; reference), Level 2 (primary), Level 3 (lower secondary), Level 4 (upper secondary), Level 5 (post-secondary non-tertiary), and Level 6 (tertiary) (Supplementary Material Table S1).

Length of residence in the local area was classified as 0–5 years (reference), 6–10 years, 11–15 years, 16–20 years, 21–25 years, 26–30 years, and > 30 years. Respondents with missing residence information were retained as a separate category in the primary analysis.

Forest ownership indicated whether respondents personally owned forest land (no [reference] versus yes), whereas social proximity to forest owners indicated whether they had relatives or friends who owned forest land (no [reference], yes, or "don't know"). "Don't know" responses were retained as a separate category in the primary analysis. Sensitivity analyses excluded respondents with missing residence information or "don't know" responses for social proximity.

Forest ownership thus refers to individual respondents' self-reported ownership, not the proportion of forest area under private ownership reported in national or regional statistics (Forest Europe, 2026). The latter measures the distribution of forest area by ownership type rather than the prevalence of forest ownership among individuals and is therefore not directly comparable.

3.3. Statistical analysis

3.3.1. Descriptive analysis

Weighted descriptive statistics were calculated to characterise forest-value perceptions across the study population. For each of the three forest-value domains, socio-cultural, provisioning, and regulating/supporting values, weighted means and standard deviations were estimated for the five Forest Europe macro-regions and for each of the 12 study countries. Country-level estimates were accompanied by 95% confidence intervals to characterise the precision of the weighted means. Descriptive summaries of the underlying survey items were also examined, including response distributions and the proportions of respondents expressing agreement, defined as responses of 4 ("agree") or 5 ("strongly agree") on the five-point response scale.

Macro-regional and country-level patterns in the three forest-value domains were subsequently visualised to assess the magnitude and distribution of geographical variation prior to multilevel modelling. These descriptive comparisons were used to characterise observed geographical patterns and were not interpreted as adjusted regional or country effects.

3.3.2. Multilevel model specification

Linear mixed-effects models were estimated separately for socio-cultural, provisioning, and regulating/supporting forest values. The primary models examined associations between forest-value perceptions, macro-region, and individual-level characteristics. The five Forest Europe macro-regions were entered as fixed effects, with North Europe as the reference category, while country was included as a random intercept to account for clustering of respondents within countries. Models included age group, gender, educational attainment, length of residence, forest ownership, and social proximity to forest owners as individual-level predictors.

Following standard multilevel modelling formulations for hierarchically structured data (Hox et al., 2017; Snijders and Bosker, 2011), the primary model can be represented as:

$$Y_{ij} = \beta_0 + \beta_R R_j + \beta_X X_{ij} + u_j + \epsilon_{ij},$$

where Y_{ij}denotes the forest-value score for respondent i in country j; $\beta_0$is the overall intercept; $R_j$represents Forest Europe macro-region to which country j belongs, with North Europe as the reference category; β_R is the vector of fixed-effect coefficients representing differences between the other macro-regions and North Europe; X_{ij} is the vector of individual-level predictors for respondent i in country j; β_X is the corresponding vector of fixed-effect coefficients for those predictors; $u_j$is the country-level random intercept; and ϵ_{ij} is the respondent-level residual error.

Models were estimated using restricted maximum likelihood (REML) (Corbeil and Searle, 1976), with country-normalised respondent weights incorporated as prior weights. This specification allowed macro-regional differences in mean forest-value scores to be estimated as fixed effects while accounting for residual clustering of respondents within countries through the country-level random intercept.

To evaluate H2, a region-only model was additionally estimated for each forest-value domain:

$$Y_{ij} = \beta_0 + \beta_R R_j + u_j + \epsilon_{ij}.$$

These models retained the same country-level random-intercept structure and weighting specification as the primary models but excluded the individual-level predictors. Macro-regional coefficients and their 95% confidence intervals were compared between the region-only and fully adjusted models to assess whether regional contrasts were attenuated after accounting for individual characteristics. Attenuation was assessed from changes in coefficient magnitude rather than changes in statistical significance.

3.3.3. Variance partitioning and robustness analyses

To quantify the extent to which forest-value perceptions clustered across broader geographical contexts, separate three-level variance-partition models were estimated with respondents nested within countries and countries nested within the five Forest Europe macro-regions (Forest Europe, 2026). These models included the same individual-level predictors as the primary models but omitted macro-region as a fixed effect, allowing residual variation to be partitioned into macro-region, country-within-region, and respondent-level components. Intraclass correlation coefficients (ICCs) were calculated for the macro-region and country levels, together with a combined contextual ICC representing the proportion of residual variation attributable jointly to macro-regional and country-level clustering. Uncertainty in the variance partition was assessed using 95% confidence intervals obtained from 1000 parametric bootstrap replications. In these prior-weighted models, the respondent-specific conditional residual variance is σ^2/w_i, where σ^2 is the estimated residual-scale variance and w_i is the respondent's normalised weight (Bates et al., 2015). Accordingly, the reported ICCs are model-scale variance ratios calculated using σ^2 at the reference weight of one; they should not be interpreted as population-average ICCs. As a sensitivity check, we also calculated contextual variance ratios using the mean respondent-specific residual variance, $\sigma^2 \times$ mean$(1/w_i)$, in the denominator. Importantly, these ICCs describe the distribution of residual variation conditional on the included individual-level predictors (Goldstein et al., 2002; Nakagawa et al., 2017). They do not quantify the proportion of outcome variance explained by those predictors or establish their relative explanatory contribution compared with geographical context (Rights and Sterba, 2019).

Several sensitivity analyses were conducted to assess the robustness of the findings. First, individual-level coefficient estimates from the primary models, which included macro-region as a fixed effect and a country-level random intercept, were compared with those from alternative three-level models specifying random intercepts for macro-region and countries nested within macro-regions (Supplementary Material Table S4). Both specifications included the same individual-level predictors and country-normalised respondent weights. This comparison

assessed whether the estimated individual-level associations were sensitive to the alternative representation of macro-regional structure. Separately, to assess the sensitivity of contextual clustering to the geographical hierarchy, combined contextual ICCs from the three-level variance-partition models were compared with those from country-only random-intercept models. Both specifications included the same individual-level predictors and country-normalised respondent weights but omitted macro-region fixed effects (Supplementary Material Table S4, Panel B). Second, the primary models were re-estimated without respondent weights to evaluate sensitivity to weighting (Supplementary Material Table S5). Third, the primary models were re-estimated in a restricted sample excluding respondents with missing residence information or "don't know" responses for social proximity to forest owners, thereby assessing sensitivity to retaining these responses as explicit categories in the primary analysis (Supplementary Material Table S6).

Model convergence and singularity were examined for all primary and sensitivity specifications. Residual-versus-fitted and quantile-quantile plots were inspected to assess model assumptions. For the primary models, scaled conditional residuals were calculated by dividing conditional response residuals by the estimated residual standard deviation. As an additional inferential sensitivity check, the bias-reduced cluster-robust variance estimator (CR2) was applied at the country level to the unweighted models, with Satterthwaite small-sample degrees-of-freedom adjustments (Pustejovsky and Tipton, 2018). CR2 inference was not applied to the weighted models because the implementation used did not support the prior-weighted mixed-model specification. Consequently, comparisons between the weighted primary-model confidence intervals and the unweighted CR2 confidence intervals reflect differences in both respondent weighting and the covariance estimation procedure (Supplementary Material Table S8).

4. Results

4.1. Sample characteristics across European macro-regions

The analytical sample comprised 12,460 respondents from 12 countries distributed across the five Forest Europe macro-regions (Table 1). Central-West Europe contributed the largest number of respondents ($n = 4192$), reflecting the inclusion of four countries, whereas each of the other macro-regions comprised two countries. The weighted mean age of respondents was 48.1 years (SD = 16.4), and women accounted for 51.4% of the sample. Overall, 42.6% of respondents had post-secondary non-tertiary or tertiary education, while 9.2% reported owning forest land. Forest ownership varied notably across macro-regions, ranging from 3.5% in South-West Europe to 24.2% in South-East Europe.

4.2. Macro-regional patterns in forest-value domains

Descriptive patterns across the five Forest Europe macro-regions showed a consistent ordering of the three forest-value domains (Fig. 2; country-level descriptive statistics are provided in Table S2a). Regulating/supporting values received the highest mean scores in all macro-regions, ranging from 4.34 in Central-West Europe to 4.52 in Central-East Europe. Socio-cultural values were also consistently high and varied relatively little across macro-regions, with weighted means ranging from 3.95 in Central-West Europe to 4.15 in Central-East Europe. In contrast, provisioning values were lower overall and displayed substantially greater macro-regional variation. They were highest in Central-East Europe (3.74), followed by South-East Europe (3.19) and North Europe (2.93), and lowest in Central-West Europe (2.50) and South-West Europe (2.59).

Thus, the unadjusted descriptive patterns suggest that macro-regional differentiation was considerably more pronounced for provisioning values than for socio-cultural or regulating/supporting values. These patterns describe variation in weighted mean scores and should be distinguished from the adjusted macro-regional contrasts and contextual variance components examined in Sections 4.4 and 4.5.

4.3. Cross-national variation within macro-regions

Country-level patterns revealed that some macro-regional averages encompassed substantial within-region heterogeneity, particularly for provisioning values (Fig. 3; Table S2a). This was most pronounced in North Europe, where the weighted mean provisioning score was 2.29 in Denmark compared with 3.58 in Sweden. Considerable variation was also evident within Central-West Europe, where provisioning values ranged from 2.00 in the Netherlands to 3.09 in Germany, with Scotland (2.23) and France (2.75) occupying intermediate positions. In Central-East Europe, provisioning values were comparatively high in both Czechia (4.03) and Romania (3.45). By contrast, provisioning scores were relatively similar between Italy (2.63) and Spain (2.56) in South-West Europe and between Croatia (3.24) and Serbia (3.15) in South-East Europe.

Cross-national variation was less pronounced for socio-cultural and regulating/supporting values. Socio-cultural means ranged from 3.84 in the Netherlands to 4.34 in Romania, while regulating/supporting means ranged from 4.18 in the Netherlands to 4.62 in Romania. These country-level patterns demonstrate that the Forest Europe macro-regions provide a useful comparative framework but do not imply homogeneity among countries within each group, particularly with respect to provisioning values.

4.4. Multilevel correlates of forest-value domains

After accounting for individual characteristics and country-level clustering, none of the macro-regional contrasts with Northern Europe had a 95% confidence interval excluding zero for any of the three forest-value domains (Table 2). This pattern was particularly notable for provisioning values, for which the pronounced descriptive differences observed across macro-regions and countries (Sections 4.2–4.3) were accompanied by relatively large but imprecisely estimated adjusted regional coefficients. For example, the provisioning coefficient for Central-East Europe relative to Northern Europe was positive but had a wide confidence interval ($\beta = 0.746$, 95% CI = [−0.163, 1.656]). Thus, the descriptive macro-regional differences should not be interpreted as precisely estimated adjusted regional effects once respondent

Table 1
Sample characteristics across European macro-regions.

Macro-region	Countries (n)	Respondents (n)	Age, mean (SD)	Female (%)	Post-secondary/tertiary education (%)	Forest ownership (%)
North Europe	2	2064	48.9 (18.0)	50.3	51.5	5.2
Central-West Europe	4	4192	48.9 (17.0)	51.5	43.8	6.8
Central-East Europe	2	2067	46.7 (15.2)	51.6	36.7	8.5
South-West Europe	2	2048	48.5 (15.6)	51.2	35.8	3.5
South-East Europe	2	2089	46.7 (14.8)	52.1	44.2	24.2
Overall	**12**	**12,460**	**48.1 (16.4)**	**51.4**	**42.6**	**9.2**

Respondent counts are unweighted. Age and percentages are calculated using country-normalised respondent weights. Post-secondary/tertiary education comprises Levels 5 and 6 of the harmonised education variable.

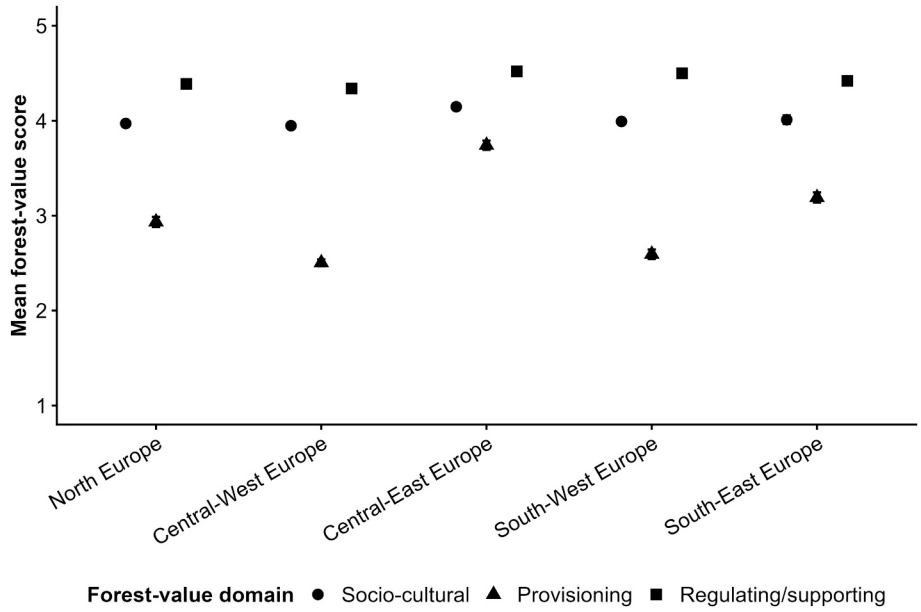


Fig. 2. Macro-regional patterns in forest-value perceptions across Europe. Points represent country-normalised weighted mean scores for the socio-cultural, provisioning, and regulating/supporting forest-value domains; error bars represent descriptive 95% confidence intervals. Scores range from 1 to 5, with higher scores indicating greater perceived importance. Countries are grouped according to the five Forest Europe macro-regions. The figure presents unadjusted descriptive patterns; adjusted macro-regional contrasts are reported in the multilevel analyses.

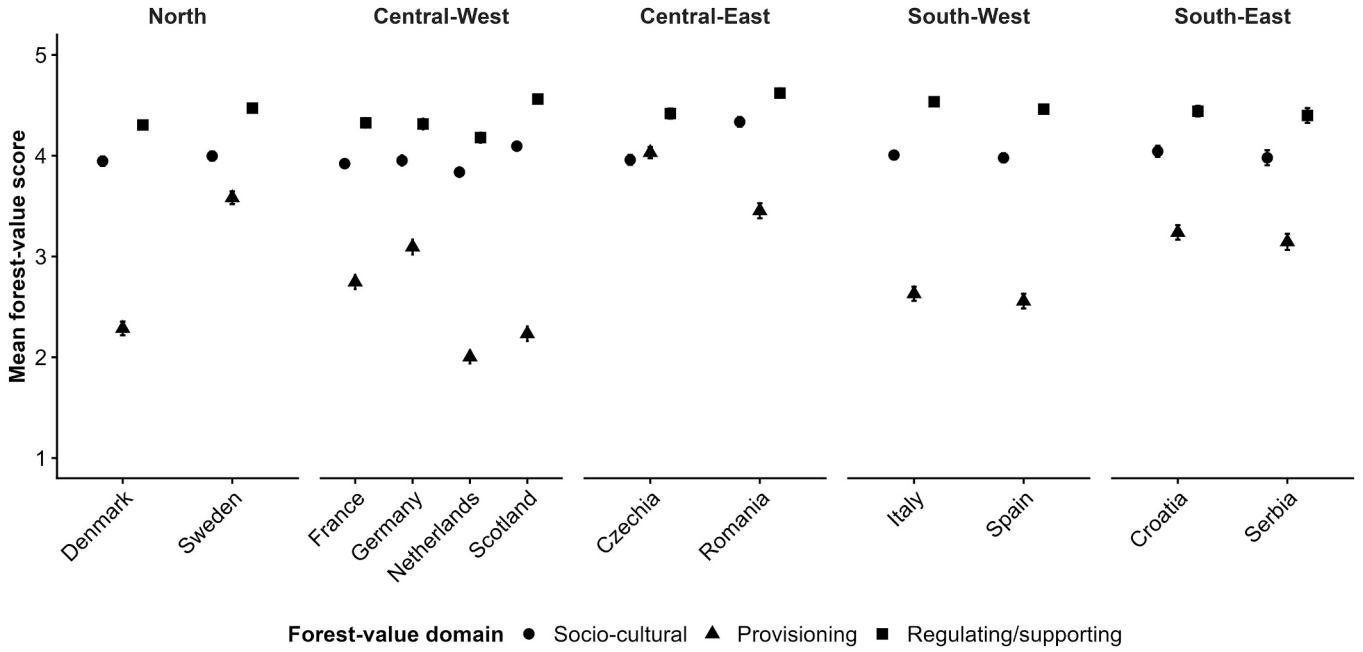


Fig. 3. Cross-national variation in forest-value perceptions within European macro-regions. Points represent country-normalised weighted mean scores for socio-cultural, provisioning, and regulating/supporting forest-value domains; error bars represent descriptive 95% confidence intervals. Countries are grouped according to the five Forest Europe macro-regions. Scores range from 1 to 5, with higher scores indicating greater perceived importance. The figure presents unadjusted descriptive patterns.

characteristics and country-level clustering are taken into account.

Comparison of the region-only and fully adjusted models showed that adjustment did not consistently attenuate macro-regional contrasts (Table S3). Across the three forest-value domains, six of the 12 regional coefficients decreased in absolute magnitude following adjustment, whereas six increased. The pattern differed across domains. For provisioning values, adjustment reduced the magnitude of all four macro-regional coefficients, although the reductions were modest for Central-West, Central-East, and South-West Europe and larger for South-East Europe ($\beta = 0.258$ to 0.092). In contrast, only one of four regional coefficients decreased in magnitude for each of the socio-cultural and regulating/supporting domains. The 95% confidence intervals for all macro-regional contrasts included zero in both model specifications. Thus, the hypothesised general attenuation of macro-regional differences following adjustment for individual characteristics was not consistently supported.

Age was the most consistent socio-demographic correlate across the three domains. Relative to respondents aged 18–26 years, all older age

Table 2
Associations between individual and macro-regional characteristics and forest-value perceptions from weighted linear mixed-effects models.

Predictor	Socio-cultural β [95% CI]	Provisioning β [95% CI]	Regulating/ supporting β [95% CI]
Macro-region			
Northern Europe (reference)	Reference	Reference	Reference
Central-West Europe	0.018 [−0.191, 0.226]	−0.395 [−1.183, 0.392]	−0.016 [−0.221, 0.190]
Central-East Europe	0.199 [−0.042, 0.440]	0.746 [−0.163, 1.656]	0.164 [−0.073, 0.402]
South-West Europe	0.044 [−0.197, 0.284]	−0.328 [−1.238, 0.581]	0.120 [−0.117, 0.357]
South-East Europe	0.051 [−0.191, 0.292]	0.092 [−0.817, 1.002]	0.076 [−0.162, 0.314]
Age			
18–26 years (reference)	Reference	Reference	Reference
27–37 years	0.159 [0.106, 0.213]	0.126 [0.051, 0.202]	0.145 [0.095, 0.195]
38–48 years	0.245 [0.191, 0.299]	0.116 [0.040, 0.192]	0.251 [0.200, 0.301]
49–59 years	0.291 [0.239, 0.344]	0.086 [0.013, 0.160]	0.365 [0.316, 0.414]
60+ years	0.284 [0.231, 0.336]	0.096 [0.022, 0.169]	0.381 [0.332, 0.430]
Gender			
Male (reference)	Reference	Reference	Reference
Female	0.105 [0.077, 0.132]	−0.030 [−0.069, 0.009]	0.092 [0.066, 0.117]
Education			
No formal education (reference)	Reference	Reference	Reference
Primary	0.152 [0.008, 0.296]	0.070 [−0.132, 0.273]	−0.025 [−0.159, 0.109]
Lower secondary	0.206 [0.088, 0.324]	0.060 [−0.105, 0.225]	0.113 [0.004, 0.222]
Upper secondary	0.215 [0.098, 0.331]	0.030 [−0.134, 0.194]	0.139 [0.031, 0.247]
Post-secondary non-tertiary	0.255 [0.139, 0.371]	−0.066 [−0.229, 0.098]	0.201 [0.093, 0.309]
Tertiary	0.176 [0.039, 0.312]	0.047 [−0.145, 0.238]	0.073 [−0.054, 0.199]
Residence length			
0–5 years (reference)	Reference	Reference	Reference
6–10 years	−0.039 [−0.101, 0.022]	0.005 [−0.082, 0.091]	0.025 [−0.032, 0.082]
11–15 years	−0.065 [−0.132, 0.001]	−0.033 [−0.127, 0.060]	0.024 [−0.037, 0.086]
16–20 years	−0.023 [−0.086, 0.040]	0.103 [0.015, 0.192]	0.028 [−0.030, 0.087]
21–25 years	0.023 [−0.041, 0.087]	0.009 [−0.080, 0.099]	0.040 [−0.020, 0.099]
26–30 years	−0.005 [−0.071, 0.061]	0.048 [−0.046, 0.141]	0.028 [−0.033, 0.090]
>30 years	−0.066 [−0.117, −0.016]	−0.010 [−0.080, 0.060]	−0.003 [−0.050, 0.043]
Missing	−0.391 [−0.452, −0.329]	0.223 [0.137, 0.310]	−0.585 [−0.643, −0.528]
Forest ownership			
No (reference)	Reference	Reference	Reference
Yes	−0.114 [−0.168, −0.061]	0.161 [0.086, 0.236]	−0.219 [−0.269, −0.169]
Social proximity to forest owners			
No (reference)	Reference	Reference	Reference
Yes	0.123 [0.083, 0.162]	0.342 [0.286, 0.398]	0.054 [0.017, 0.091]
Don't know	−0.032 [−0.083, 0.018]	0.147 [0.077, 0.218]	−0.012 [−0.059, 0.034]

Entries are adjusted fixed-effect coefficients (β) with 95% confidence intervals from weighted linear mixed-effects models with country-level random intercepts. Models were estimated using country-normalised respondent weights. Reference categories are indicated in the table. Positive coefficients indicate higher forest-value scores and negative coefficients lower scores relative to the corresponding reference category. Confidence intervals excluding zero indicate statistical evidence of an association at the two-sided 5% level. All models included 12,460 respondents from 12 countries. Respondents with missing residence information were retained as a separate category in the primary analysis to avoid case-wise deletion.

groups reported higher socio-cultural, provisioning, and regulating/supporting values, with all corresponding 95% confidence intervals excluding zero in the primary models. The age gradient was particularly pronounced for regulating/supporting values, with coefficients increasing from 0.145 (95% CI = [0.095, 0.195]) among respondents aged 27–37 years to 0.381 (95% CI = [0.332, 0.430]) among those aged 60 years or older. A broadly similar, although less monotonic, pattern occurred for socio-cultural values, whereas age differences in provisioning values were positive but smaller.

Associations with gender and education differed across value domains. Women reported higher socio-cultural (β = 0.105, 95% CI = [0.077, 0.132]) and regulating/supporting values (β = 0.092, 95% CI = [0.066, 0.117]) than men, whereas the estimate for provisioning values was small and its confidence interval included zero. Compared with respondents with no formal education, all higher education categories were positively associated with socio-cultural values, with their 95% confidence intervals excluding zero. For regulating/supporting values, positive associations were observed for lower-secondary, upper-secondary, and post-secondary non-tertiary education, whereas the confidence intervals for primary and tertiary education included zero. Provisioning values showed no clear educational gradient, with confidence intervals including zero for all education categories. Among respondents with reported residence information, residence length showed comparatively limited and inconsistent associations across the three domains. The clearest associations were lower socio-cultural values among respondents resident for more than 30 years (β = −0.066, 95% CI = [−0.117, −0.016]) and higher provisioning values among those residents for 16–20 years (β = 0.103, 95% CI = [0.015, 0.192]), relative to respondents resident for 0–5 years.

Forest ownership and social proximity to forest owners showed pronounced domain-specific associations. Forest owners reported higher provisioning values than non-owners (β = 0.161, 95% CI = [0.086, 0.236]), but lower socio-cultural (β = −0.114, 95% CI = [−0.168, −0.061]) and regulating/supporting values (β = −0.219, 95% CI = [−0.269, −0.169]). Respondents with social proximity to forest owners, measured as having relatives or friends who owned forest land, reported higher values across all three domains than those without such social proximity. The strongest association was observed for provisioning values (β = 0.342, 95% CI = [0.286, 0.398]), compared with socio-cultural (β = 0.123, 95% CI = [0.083, 0.162]) and regulating/supporting values (β = 0.054, 95% CI = [0.017, 0.091]). Respondents who

answered "Don't know" regarding social proximity also reported higher provisioning values than those reporting no social proximity (β = 0.147, 95% CI = [0.077, 0.218]), while the corresponding associations for the other two domains had confidence intervals including zero.

Overall, the multilevel models indicate greater consistency in the association of age with forest values across domains, while gender, education, forest ownership, and social proximity exhibited more domain-specific patterns. The absence of precisely estimated adjusted macro-regional contrasts also contrasts with some of the descriptive regional patterns reported above, particularly for provisioning values. The extent to which residual variation remained clustered at the macro-regional and country levels is examined through variance partitioning in Section 4.5.

4.5. Contextual variance and clustering

Variance partitioning revealed marked differences in contextual clustering across the three forest-value domains (Table 3; underlying variance components and corresponding ICC estimates are provided in Table S7). For socio-cultural values, only 2.19% of the residual variance was attributable jointly to macro-regional and country-level clustering (95% CI = 0.65–4.58%), with the estimated macro-regional component at the boundary of zero. Similarly, contextual clustering accounted for 2.60% of the residual variance in regulating/supporting values (95% CI = 0.87–5.38%), comprising point estimates of 0.18% at the macro-regional level and 2.43% at the country level. The corresponding residual proportions at the respondent level were 97.81% for socio-cultural values and 97.40% for regulating/supporting values.

Provisioning values exhibited a markedly different variance structure. The combined contextual ICC was 21.22% (95% CI = 8.08–37.90%), with point estimates of 7.48% attributable to macro-regional clustering and 13.74% to country-level clustering within macro-regions. The confidence interval around the macro-regional component was particularly wide (95% CI = 0.00–26.29%), indicating considerable uncertainty in the precise allocation of contextual variance between the macro-regional and country levels. Nevertheless, the combined contextual component was substantially larger for provisioning values than for either socio-cultural or regulating/supporting values.

Table 3
Variance partitioning of forest-value perceptions across macro-regional, country, and respondent levels.

Forest-value domain	Macro-region ICC, % (95% CI)	Country ICC, % (95% CI)	Combined contextual ICC, % (95% CI)	Residual proportion, % (95% CI)
Socio-cultural	0.00 (0.00–1.78)	2.19 (0.39–4.10)	2.19 (0.65–4.58)	97.81 (95.42–99.35)
Provisioning	7.48 (0.00–26.29)	13.74 (3.68–26.63)	21.22 (8.08–37.90)	78.78 (62.10–91.92)
Regulating/supporting	0.18 (0.00–2.52)	2.43 (0.53–4.93)	2.60 (0.87–5.38)	97.40 (94.62–99.13)

ICC = intraclass correlation coefficient. Estimates are derived from weighted three-level linear mixed-effects models, with respondents nested within countries and countries nested within the five Forest Europe macro-regions. Models included the individual-level predictors used in the primary analyses but omitted macro-region as a fixed effect to permit estimation of macro-regional variance. The combined contextual ICC represents the proportion of residual variance attributable jointly to macro-regional and country-level clustering. The ICCs are model-scale ratios calculated using the residual-scale variance at a reference weight of one. Under the prior-weighted model, respondent-specific residual variances equal σ^2/w_i; consequently, these ICCs should not be interpreted as population-average variance proportions. The respondent-level residual represents the remaining residual variation after adjustment for the included individual-level predictors; it should not be interpreted as variance explained or unexplained by those predictors. Confidence intervals were obtained from 1000 parametric bootstrap replications. Separate macro-regional and country-level components should be interpreted cautiously given the small number of macro-regions (5) and countries (12).

Overall, the variance decomposition indicates that residual contextual clustering was limited for socio-cultural and regulating/supporting values but considerably stronger for provisioning values. Most residual variation in all three domains remained at the respondent level, although the residual proportion was substantially lower for provisioning values (78.78%, 95% CI = 62.10–91.92%) than for socio-cultural (97.81%, 95% CI = 95.42–99.35%) and regulating/supporting values (97.40%, 95% CI = 94.62–99.13%). These variance proportions describe the distribution of residual variation after adjustment for the included individual-level predictors and should not be interpreted as the proportion of total outcome variance explained or unexplained by those predictors.

4.6. Robustness and sensitivity analyses

Individual-level associations were stable across alternative geographical specifications, with all 60 coefficients retaining their direction and 95% confidence-interval classification (maximum $|\Delta\beta| = 0.0029$; Table S4, Panel A). Combined contextual ICCs were also similar between country-only and three-level random-intercept models: 2.19% under both specifications for socio-cultural values, 20.41% versus 21.22% for provisioning values, and 2.58% versus 2.60% for regulating/supporting values (Table S4, Panel B).

Removing respondent weights produced limited changes in fixed-effect estimates, with 70 of 72 coefficients retaining their direction and 71 retaining their confidence-interval classification (Table S5, Panel A). Contextual ICCs likewise remained similar, particularly for provisioning values (21.22% weighted versus 21.32% unweighted; Table S5, Panel B).

Restricting the sample to 10,382 respondents yielded unchanged directions for 61 of 66 comparable coefficients and unchanged confidence-interval classifications for 58 (Table S6, Panel A). Notably, all four provisioning age coefficients remained positive, but their confidence intervals included zero, as did the socio-cultural forest-ownership coefficient. Nevertheless, the provisioning contextual ICC remained comparatively high (23.41%, versus 21.22% in the full sample), while contextual clustering for the other domains remained below 3% (Table S6, Panel B).

All primary models converged without singularity. Country-clustered CR2 inference retained the same confidence-interval classification for all 12 macro-regional contrasts and 50 of 60 individual-level coefficients (83.3%) compared with the weighted primary models (Table S8). Agreement between conventional and CR2 inference within the unweighted models was 49 of 60 coefficients (81.7%). These results indicate some sensitivity in individual-level inferences, with differences in the primary comparison reflecting both weighting and uncertainty estimation, and warrant caution given the 12 country clusters.

5. Discussion

This study examined how socio-cultural, provisioning, and regulating/supporting forest values are structured across individuals, countries, and broader European macro-regions. Four findings are particularly important. First, after adjustment for the included individual-level characteristics, respondent-level residual variation exceeded the combined country- and macro-region-level variation in all three domains, supporting H1. Second, contextual clustering differed markedly across domains: provisioning values showed substantially greater country- and macro-region-level clustering than socio-cultural and regulating/supporting values, supporting H3. Third, although descriptive differences were evident across Forest Europe macro-regions (Forest Europe, 2026), particularly for provisioning values, none of the

adjusted macro-regional contrasts had 95% confidence intervals excluding zero. Adjustment for individual characteristics also did not consistently attenuate these contrasts, providing only limited support for H2. Lastly, individual characteristics showed domain-specific associations, indicating that social differentiation in forest values is not uniform across value domains. These findings show that the relative importance of individual and geographic structuring depends on the forest-value domain considered.

5.1. Forest-value domains differ in their geographical structuring

The clearest difference among forest-value domains concerned their geographical structuring. Country and macro-region together accounted for 21.22% of residual variation in provisioning values (95% CI = [8.08, 37.90]), compared with only 2.19% [0.65, 4.58] for socio-cultural and 2.60% [0.87, 5.38] for regulating/supporting values. For provisioning values, 13.74% [3.68, 26.63] occurred between countries and 7.48% [0.00, 26.29] between macro-regions, although the latter estimate is imprecise given its wide confidence interval and only five macro-regions. Respondent-level residual variation nevertheless remained the largest component across all domains after adjustment for the included individual-level characteristics.

This domain-specific pattern is consistent with European research documenting geographic variation in forest perceptions, ecosystem-service preferences, and material forest use (Derks et al., 2026; Eriksson et al., 2015; Lovrić et al., 2020; Roitsch et al., 2026). Material forest use is particularly geographically differentiated: non-wood forest-product collection varies considerably across Europe, generally increasing from Western to Eastern Europe (Lovrić et al., 2020). Forest-owner studies likewise report cross-country variation in production, economic, environmental, and other management orientations (Feliciano et al., 2017; Quiroga et al., 2019; Westin et al., 2023). Although actual forest use and owner orientations differ from public perceptions, these studies provide a plausible context for the stronger geographic clustering of provisioning values observed here. Our findings extend this literature by showing that geographic differentiation concerns not only average perceptions or preferences but also the proportion of residual variation clustered geographically after adjustment for the included individual-level characteristics, which differs markedly among value domains.

National forest contexts may contribute to this pattern. European countries differ substantially in ownership structures, property and forest-use rights, and historical trajectories of forest governance (Erdozain et al., 2026; Makrickiene et al., 2025; Nichiforel et al., 2018; Weiss et al., 2019). Together with geographic differences in material forest use, these conditions may contribute to stronger contextual differentiation in provisioning values. However, these factors were not modelled directly and should be regarded as potential explanations rather than demonstrated mechanisms. Variance partitioning identifies where variation is clustered, not the processes generating it.

By contrast, approximately 97–98% of residual variation in socio-cultural and regulating/supporting values was attributable to the respondent-level residual component. This does not imply geographic invariance, since previous studies report geographic differences in ecological, cultural, and other forest perceptions and preferences (Derks et al., 2026; Eriksson et al., 2015; Roitsch et al., 2026). Rather, geographic context accounted for a comparatively small share of variation in these domains. Forest values do not share a common geographic structure: provisioning values showed substantially greater contextual clustering, whereas socio-cultural and regulating/supporting values were characterised predominantly by within-context individual heterogeneity.

5.2. Descriptive regional differences do not imply strong adjusted macro-regional effects

Descriptive macro-regional differences were most pronounced for provisioning values, whose weighted mean ranged from 2.50 in Central-West Europe to 3.74 in Central-East Europe. However, none of the adjusted macro-regional contrasts had 95% confidence intervals excluding zero. This qualifies rather than contradicts previous evidence of geographic differentiation in European forest perceptions and preferences (Derks et al., 2026; Eriksson et al., 2015; Roitsch et al., 2026): observed regional differences do not necessarily represent independent adjusted associations of broad regional context, particularly where macro-regions contain substantial internal heterogeneity.

H2 thus received only limited support. Adjustment for age, gender, education, residence duration, forest ownership, and social proximity reduced the absolute magnitude of six of the twelve regional coefficients and increased that of the remaining six, although all four provisioning contrasts attenuated. Population composition may therefore contribute to some geographic differences, particularly in provisioning values, but does not provide a general explanation for the macro-regional patterns.

Country-level differences within macro-regions further illustrate this heterogeneity. Provisioning values differed markedly between Denmark (2.29) and Sweden (3.58) within North Europe and between the Netherlands (2.00) and Germany (3.09) within Central-West Europe, while differences between Italy and Spain and between Croatia and Serbia were much smaller. Similar combinations of broad geographic patterning and country-specific variation have been reported for forest preferences, material forest use, and forest-owner orientations (Derks et al., 2026; Feliciano et al., 2017; Lovrić et al., 2020; Westin et al., 2023). European countries also differ in forest ownership and use rights, governance trajectories, and how forest functions are operationalised (Di Cintio and Portoghesi, 2026; Nebasifu et al., 2025; Nichiforel et al., 2018; Weiss et al., 2019). Although these factors do not directly explain the present results, they reinforce why countries within the same macro-region should not be assumed to represent equivalent forest contexts.

The five Forest Europe macro-regions are thus better interpreted as comparative geographic groupings than as homogeneous "forest cultures." This is particularly evident for provisioning values, for which the country-level variance component (13.74%) exceeded the macro-regional component (7.48%). More broadly, the findings highlight the distinction between descriptive means, adjusted contrasts, and variance components: the first describe average geographic differences, the second assess contrasts after adjustment for measured characteristics and country clustering, and the third quantify how much residual variation is geographically clustered. Our results thus add that geographic differentiation in forest values is both domain- and scale-dependent, with provisioning values showing the strongest contextual clustering and substantial differentiation occurring among countries within broader macro-regions.

5.3. Individual characteristics are associated with forest values in domain-specific ways

Individual characteristics differentiated forest values across domains, with age showing the most consistent pattern. Relative to respondents aged 18–26 years, older respondents reported higher socio-cultural and regulating/supporting values, with the clearest increasing pattern observed for regulating/supporting values, alongside smaller positive differences in provisioning values. Age-related differentiation has similarly been reported for forest perceptions and ecosystem-service valuation, although its direction and magnitude vary across forest functions and contexts (Janeczko et al., 2023; Paletto et al., 2013; Roitsch et al., 2026). Our results extend this evidence by showing positive associations with older age categories across all three domains after accounting for other individual characteristics and country clustering.

Possible explanations include accumulated forest experience, changing relationships with forests over the life course, and generational differences in environmental orientations (Janeczko et al., 2023; Zoeller et al., 2021). However, the cross-sectional design cannot distinguish life-course from cohort effects, and age should be interpreted as differentiating the importance attached to multiple forest functions rather than as evidence of a particular underlying mechanism.

Education and gender showed more domain-specific patterns. Compared with respondents with no formal education, all other education categories were positively associated with socio-cultural values, whereas positive associations with regulating/supporting values were observed for lower-secondary, upper-secondary, and post-secondary non-tertiary education. No education category showed a clearly estimated association with provisioning values, and the education coefficients did not increase monotonically across successive levels. These patterns are broadly consistent with previous research linking education particularly to ecological, cultural, and other non-material forest perceptions (Häyrinen et al., 2015; Janeczko et al., 2023; Palliwoda and Priess, 2021; Roitsch et al., 2026; Thiemann et al., 2022). Similarly, women reported higher socio-cultural and regulating/supporting values than men, whereas the provisioning difference was small and its confidence interval included zero, corresponding with previous evidence of gender differences in cultural and regulating forest values but less consistent differences in provisioning values (Hegetschweiler et al., 2022; Janeczko et al., 2023). Together, these patterns indicate that education and gender differentiate particular dimensions of forest valuation rather than corresponding to uniformly stronger or weaker forest values.

Residence duration showed little consistent association with any value domain. This does not imply that place-based relationships are unimportant; rather, research suggests that forest perceptions and experiences are related to more substantive dimensions of place and forest engagement, including personal connection, meanings, use, accessibility, and surrounding environmental characteristics (Duşcu and Rîşnoveanu, 2025; Ford et al., 2026; Salak et al., 2026). Time lived in an area does not indicate whether individuals use nearby forests or develop attachment and personal meanings around them. Residence duration may be a relatively coarse proxy for place-based relationships, potentially obscuring dimensions of forest connection and engagement more directly relevant to forest values.

Overall, the findings suggest that associations between individual characteristics and forest-value perceptions vary across forest functions rather than following a uniform pattern across all three domains. The same individual characteristic may distinguish some value domains but not others, while conventional socio-demographic indicators provide only partial proxies for the social and relational processes underlying forest valuation. Together with the geographic patterns in Sections 5.1 and 5.2, these findings reinforce the need to consider both the value domain and the individual and contextual levels at which variation occurs.

5.4. Forest ownership and social proximity to forest owners reveal contrasting value orientations

Personal forest ownership and social proximity to forest owners showed contrasting associations with forest values. Forest owners reported higher provisioning but lower socio-cultural and regulating/supporting values than non-owners, whereas respondents with relatives or friends who owned forest land reported higher values across all three domains, most strongly for provisioning values. These patterns indicate that direct ownership and social connections to forest owners capture different dimensions of people's relationships with forests.

The positive association between forest ownership and provisioning values is consistent with research showing that private forest ownership encompasses diverse economic, recreational, conservation, and multi-objective orientations (Ficko et al., 2019; Mazziotta et al., 2025; Tiebel et al., 2022). Importantly, owners may value regulating and cultural services alongside provisioning benefits, reflecting amenity, conservation, identity, and stewardship considerations as well as material objectives (Joa and Schraml, 2020; Juutinen et al., 2022; Tiebel et al., 2021). These findings do not imply that forest owners attach little importance to socio-cultural or regulating/supporting forest functions, nor do they establish how individuals prioritise the different value domains.

Social proximity showed a different pattern. Having relatives or friends who owned forest land was positively associated with all three value domains, consistent with evidence that people's relationships with forests can encompass social, cultural, and symbolic dimensions beyond direct economic use (Elands et al., 2004; Salak et al., 2026). Our findings extend this perspective by showing that an indirect social connection to forest ownership is associated with multiple value domains, although most strongly with provisioning values. However, the measure captures only whether respondents had relatives or friends who owned forest land, not the nature or frequency of interaction, shared forest experiences, information exchange, or involvement with those forests. The mechanisms underlying these associations therefore remain unresolved.

Overall, the contrasting associations indicate that personal ownership and social proximity should not be treated as interchangeable forms of connection to forests. Personal ownership represents a direct relationship with forest land, whereas social proximity captures an indirect connection through relatives or friends who own forests. Distinguishing these forms of connection may help clarify how different relationships with forests correspond to different dimensions of public forest values.

5.5. Implications for comparative forest research and governance

The findings have implications for the geographic and social scales at which forest values are compared and considered in governance. Provisioning values displayed substantially greater country- and macro-region-level clustering than socio-cultural and regulating/supporting values, showing that geographic structuring differs by domain. Treating forest values as a single construct or relying only on regional means can obscure where heterogeneity is located. Variance partitioning complements mean comparisons by distinguishing average geographic differences from the extent to which perceptions are geographically clustered.

For governance, the relevant scale for considering societal values may likewise depend on the forest function concerned. Public perceptions of provisioning benefits may require greater sensitivity to national and sub-European contexts, although substantial individual variation remained even for provisioning values. Moreover, none of the adjusted macro-regional contrasts had confidence intervals excluding zero, while substantial differences occurred between countries within the same macro-region. Broad regional classifications may thus provide useful comparative structure without defining homogeneous “forest cultures” or publics.

Individual-level results reinforce this conclusion. Age, education, gender, forest ownership, and social proximity did not differentiate forest values uniformly, while residence duration captured little systematic variation. In particular, personal ownership was associated with higher provisioning values but lower socio-cultural and regulating/supporting values, whereas having relatives or friends who owned forest land was positively associated with all three domains. Such patterns caution against inferring fixed value orientations from broad stakeholder categories or treating different forms of forest connection as interchangeable.

Together, the findings support a domain-sensitive and multilevel understanding of public forest values. European-level frameworks remain important for coordinating shared forest objectives, but no single broad geographic scale fully captures the heterogeneity in forest-value perceptions observed across the participating countries. Comparative research and governance would thus benefit from combining cross-European perspectives with attention to national context and within-

country heterogeneity.

5.6. Limitations and future research

Several limitations should be considered. First, despite the large respondent sample across 12 countries, the number of higher-level units was limited, particularly the five Forest Europe macro-regions (Forest Europe, 2026). The wide confidence interval around the provisioning macro-region ICC (7.48%, 95% CI = [0.00, 26.29]) illustrates this uncertainty. Separate country and macro-region variance components should thus be interpreted cautiously, while the substantially greater combined contextual clustering of provisioning values relative to the other domains is more informative. The Forest Europe classification may also conceal heterogeneity among countries within macro-regions.

Second, respondents were recruited through online panels, and post-stratification weights were used to improve alignment with national adult populations. Although results were largely robust to unweighted estimation, the analysis remains model-based rather than fully design-based. The 12 countries were also selected to represent variation in European forest and socio-cultural contexts (SUPERB, 2022) rather than through probability sampling, limiting generalisation beyond the participating countries.

Third, the cross-sectional design identifies associations rather than causal relationships. Age-related associations cannot distinguish life-course from cohort differences, while associations with forest ownership and social proximity should not be interpreted as effects of owning forest land or having relatives or friends who do so. Longitudinal or repeated cross-sectional studies could help distinguish these temporal processes.

Fourth, the country and macro-region variance components identify where residual variation is clustered, not the mechanisms producing it. Contextual characteristics such as forest conditions, ownership structures, forest-sector importance, governance and property-right arrangements, accessibility, urbanisation, and material forest use were not modelled directly. Incorporating such predictors could help explain the stronger geographic clustering of provisioning values.

Lastly, the three indices represent the forest-value dimensions captured by the questionnaire (see Supplementary Material, Table S1) rather than the full range of ways people value forests. Relational, intrinsic, and other instrumental dimensions may not be fully represented, while some predictors were measured in broad categories that may obscure finer differences among respondents. Residence duration does not capture the nature or intensity of relationships with local forests, and social proximity identifies relatives or friends who own forest land without measuring interaction, shared experiences, information exchange, or involvement with those forests. Future research could use more direct measures of forest use, place attachment, personal connection, and forest-related social relationships.

6. Conclusion

This study shows that forest values across the 12 European countries included in this study are characterised by both respondent-level heterogeneity and geographic differentiation, with patterns that differ across value domains. After adjustment for the included individual-level characteristics, the respondent-level residual component was largest across all three domains, but provisioning values showed substantially greater contextual clustering, with country and macro-region jointly accounting for about one-fifth of residual variation compared with only 2–3% for socio-cultural and regulating/supporting values. Yet none of the adjusted macro-regional contrasts had confidence intervals excluding zero, and substantial country-level heterogeneity occurred within some macro-regions. Regional mean differences should not be equated with strong or uniform geographic structuring.

Individual characteristics also differentiated forest values by domain. Age showed the most consistent positive associations, while gender, education, residence duration, forest ownership, and social proximity showed more varied patterns. Notably, personal forest ownership was associated with higher provisioning values but lower socio-cultural and regulating/supporting values, whereas having relatives or friends who owned forest land was positively associated with all three domains, most strongly with provisioning values. Direct ownership and social connections to forest owners thus represent distinct rather than interchangeable forms of connection to forests.

By combining cross-national comparison, individual-level modelling, and multilevel variance partitioning, this study advances comparative forest-perception research from documenting geographic differences to examining where heterogeneity is situated and how it differs across value domains. The findings underscore the importance of distinguishing value domains and geographic scales and of recognising both national context and heterogeneity among respondents within countries rather than treating broad geographic or stakeholder categories as homogeneous.

CRediT authorship contribution statement

Moses Kazungu: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Project administration. **Marcel Hunziker:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Ethics statement

Ethical approval was not required for this study, as it collected non-sensitive data on perceptions and attitudes. Data processing was conducted in accordance with the Swiss Federal Act on Data Protection (nFADP) and relevant European Union regulations, including the General Data Protection Regulation (GDPR; Regulation (EU) 2016/679). All procedures ensured the protection of personal data and the privacy of participants throughout the research process.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2026.103955.

Data availability

The dataset used in this study forms part of a larger survey programme and will be made publicly available through the institutional research data repository EnviDat following completion of the ongoing analyses. Supporting information is provided in the Supplementary Material. The analysis code and aggregated data supporting the findings of this study are publicly available in the GitHub repository.

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