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RESEARCH ARTICLE

How forests may support psychological restoration: Modelling forest characteristics based on perceptions of forestry experts and the general public

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Abstract

1. Spending time in forests benefits human well-being, but the importance of forest characteristics on well-being is unclear. This knowledge could help guide forest management decisions to improve outcomes for both people and nature.
2. The overall aim of this study was to investigate how psychological restoration, defined as psychological recovery processes in nature, may be supported by forest characteristics. We (1) investigated how perceptions of restoration (perceived restorativeness) were linked to specific forest characteristics. More specifically, we selected attributes included in nature protection legislation in Germany (beauty, diversity and uniqueness) as the basis to evaluate how forest characteristics were related to perceived restorativeness. Additionally, we (2) tested differences in the assessments of these attributes between forestry experts and people from the general public. Based on the results of the first two objectives (1, 2), we (3) predicted how forest management that affects forest characteristics may impact psychological restoration today and in the future.
3. We developed a perceived restorativeness model based on attributes stated in the German Nature Conservation Act and specific forest structure variables. Drawing from the literature, we included perceived naturalness as an additional key predictor for restoration. Forestry experts and participants from the general public were then asked to rate computer-generated forest stand pictures on these attributes and restorativeness.
4. We found that all attributes were positively associated with perceived restorativeness, but perceived beauty was most important. Perceived uniqueness was statistically significant, but the strength of the relationship was weak. Mixed

forests were rated as most beautiful, while coniferous forest stands were rated as least beautiful. The general public gave higher ratings than forestry experts on all attributes, but the pattern was similar. Based on participant ratings, forests left without management (Set-aside), followed by forests with management aiming for resilience to climate change (Adaptation forestry), both supporting biodiversity conservation, showed the highest perceived restorativeness over the course of 100 years.

5. Based on our results, it could be recommendable to increase forest diversity, especially in areas with many visitors. However, more nuanced knowledge involving diverse stakeholders is needed to inform forest management decisions on landscape level.

KEYWORDS
forest diversity, forest management, forest structure, human restoration, perceived beauty, perceived restorativeness, scenario simulation, well-being

1 | INTRODUCTION

By 2050, almost 70% of the world's population is estimated to live in urban environments (United Nations, 2019). At the same time, biodiversity is decreasing rapidly around the globe, posing urgent challenges for both nature protection and human well-being (Convention on Biological Diversity, 2022; IPBES, 2019). Urbanization is associated with a higher risk of mental disorders, such as depression and anxiety, where the lack of nature contact has been recognized as one of several risk factors (Ventriglio et al., 2021). It has been theorized that nature supports human well-being through psychological restoration (Kaplan, 1995; Ulrich, 1983). Stressors in daily life can deplete psychological resources, and these resources need to be replenished to maintain one's well-being. Natural environments can support these recovery processes by replenishing human's limited capacity for directed attention (Attention Restoration Theory, Kaplan, 1995), by activating positive emotions and stress recovery (Stress Reduction Theory, Ulrich, 1983, 1993; Ulrich et al., 1991), or by inducing feelings of security (Calm and Connection Theory, Grahn et al., 2021; Prospect-Refuge-Theory, Appleton, 1975). While Prospect–Refuge theory (Appleton, 1975) does not explicitly focus on psychological restoration, it does predict people's preference for environments that offer both opportunities to observe and to hide from potential hazards. Indeed, contact with nature is associated with better mental health and human well-being (e.g. Aerts et al., 2018; Barragan-Jason et al., 2023; Bowler et al., 2010; Bratman et al., 2019; Marselle et al., 2021; McMahan & Estes, 2015) and similar benefits were found for forests specifically (Stier-Jarmer et al., 2021). Nevertheless, research on forests and human well-being often does not consider specific characteristics of the examined forests (Bach Pagès et al., 2020). While there are studies that compare the restorative potential of different forest stands, for instance, based on how they are managed (Simkin et al., 2021; see also Martens et al., 2011; Takayama et al., 2017), studies that aim to disentangle the relationship between specific forest variables (e.g. percentage of conifers or the height of trees) and psychological restoration are scarce. Exploring the relevance of particular forest variables for restoration would not only start to fill this research gap but the knowledge gained could also be used to evaluate the impact of different forest management strategies on the potential of present and future forests for psychological restoration.

1.1 | Beauty, diversity, naturalness and uniqueness as indicators for restorativeness

In Germany, the Nature Conservation Act (Bundesnaturschutzgesetz (BNatSchG), 2022), § 1 (1) recognizes the impact of nature on humans by emphasizing nature as a necessity for human life that needs to be protected for present and future generations. It requires nature and landscape to be 'protected in a way that [...] ensures the diversity, uniqueness,[1] beauty of nature, as well as their recreational value'. Moreover, the relevance of nature's diversity, beauty and naturalness for human well-being is reflected in theories and previous findings in environmental psychology and landscape preference research. For instance, natural environments with certain qualities offer opportunities for people to restore in order to maintain their well-being. These are *extent*, that is, that the site should be large enough to give space to the experience of scope and connectedness, as well as *fascination*, that is, a place that endows with stimuli to capture and hold one's attention. Moreover, the environment should induce a feeling of *being away* from everyday life, and it should be *compatible* with a person's

[1]The original term stated in the German Nature Conservation Act is 'Eigenart'. While there are several possible translations, in the following, we use the term 'uniqueness', referring to the unique/special characteristics of a certain landscape.

preferences, interests and intrinsic motivation to visit a natural environment (Kaplan, 1995). These qualities combine to the perceived restorativeness of an environment (Hartig et al., 1997). Other research has used perceived sensory dimensions (Grahn & Stigsdotter, 2010; Stoltz & Grahn, 2021) as indicators for the restorative potential of natural environments, namely Serene, that is, freedom from noise and other disturbances, such as logging and left residues, Shelter, that is, places where one can retreat and see the surroundings without being seen, Diverse, that is, perceived structural and biological diversity, Cohesive, that is, the provision of spatial extent and structural unity, such as in mature beech or pine forests, and Natural, that is, that the environment seems characterized by natural, rather than human influence. (Bio)diversity of natural environments has been linked to restoration and human well-being (Aerts et al., 2018; see also, e.g. Dallimer et al., 2012; Fuller et al., 2007; Hoyle et al., 2017; Marselle et al., 2016). Perceived beauty has been positively associated with perceived restorativeness (Simkin et al., 2021) and affective restoration (Van den Berg et al., 2003), as has perceived naturalness (Carrus et al., 2013; Hoyle et al., 2019; Marselle et al., 2016). To the best of our knowledge, there is no research investigating the relationship between perceived uniqueness and psychological restoration. However, to cover all attributes of the German Nature Conservation Act, we decided to include uniqueness as an explorative variable in our study. Naturalness is not explicitly stated in § 1 (1) of the act but is often part of landscape assessments (Hermes et al., 2018) and, as mentioned above, present in the literature on psychological restoration in natural environments and therefore included in the present study. We thus investigate how forest stands are evaluated based on attributes of nature protected by legislation (Bundesnaturschutzgesetz (BNatSchG), 2022), specifically the beauty, diversity, naturalness and uniqueness of a natural environment, and whether these attributes may also support psychological restoration.

1.2 | Forest characteristics and restorativeness indicators

Landscape preference research points towards the preference of people for diverse forest stands in terms of tree species composition and age structure (Ebenberger & Arnberger, 2019; Filyushkina et al., 2017; Füger et al., 2021; Giergiczny et al., 2015; Silvennoinen et al., 2001). Moreover, homogenous conifer stands have been judged as the least aesthetically appealing when compared with mixed forest stands, possibly due to their higher level of visual diversity (Füger et al., 2021). Instead, forests with a large proportion of deciduous trees have been found to be more restorative than coniferous forests (Annerstedt et al., 2010).

Forest characteristics such as the height of the trees, stand density or species composition are strongly affected by the forestry management regime applied. In Bavaria, commonly applied regimes are variations of Continuous cover forestry and Adaptation forestry (to climate change) with some proportions of Rotation forestry and Set-aside (Toraño Caicoya, Poschenrieder, et al., 2023). These management regimes use certain combinations of silvicultural treatments during the succession of a forest stand. For instance, in Rotation forestry, a production-oriented regime applies repeated thinnings and finally clear cuttings, leading to homogenized, mono-layered forest stands. In contrast, Continuous cover forestry (CCF) leads to higher structural diversity compared with Rotation forestry by focusing thinning events on target trees and initiated regeneration by shelterwood coups. Adaptation forestry aims to manage forests in a climate-resilient way by fostering a diverse tree diameter and height distribution, as well as a diverse species composition with a focus on broadleaved species. Set-aside leaves previously managed areas without management, meaning that all management activities are stopped to allow natural processes to continue without interference (Toraño Caicoya, Poschenrieder, et al., 2023); see more detailed descriptions of the forestry management regimes in Supporting Information S1. Thus, by affecting certain forest characteristics, the applied forest management regime plays an important role in how people perceive different forests and, thereby, in how different kinds of forests could affect psychological restoration. By including this broad range of forest management regimes, from conservation to high productivity-oriented silviculture, we contribute to management discussions at the European level. Here, current policy implementations aim at improving the multifunctionality of forest landscapes and often face dilemmas regarding biodiversity conservation and the provision of non-woody ecosystem services while also improving wood production (Toraño Caicoya, Poschenrieder, et al., 2023; Toraño Caicoya, Vergarechea, et al., 2023).

1.3 | Individual differences in nature perception and experience

It is important to acknowledge that previous research has revealed differences among (groups of) individuals in how they perceive and experience nature. The reason could be that, for example, beauty is not an immediately significant characteristic of a natural environment (Lothian, 1999; Nehamas, 2007). Beauty is not attributed exclusively to the subject or the object, but to the relationship between them (Sartwell, 2015). This relationship could be influenced by, for example, education, experience of working with or valuing nature, ecological knowledge and affect (Daniel, 2001; Sevenant & Antrop, 2010; Tyrväinen et al., 2003), possibly with the more experienced using more senses, such as smelling and hearing, in the interpretation and valuation of the natural environment (Gyllin & Grahn, 2015). In an eye-tracking study, Dupont et al. (2015) found that landscape-related experts focus on other aspects of landscape photographs than laymen, which may be related to different preferences between the groups. Indeed, preferences have been found to be influenced by professional background (Jensen, 1993; Petucco et al., 2013). For instance, when ranking photographs based on recreational preference, forestry experts focused more on treatment type, while participants from the general public focused more on, for example, overall pattern of openness (Petucco et al., 2013). Interestingly, ecological knowledge and nature connectedness (i.e., how people value their relationship with nature, Nisbet et al., 2009) may also influence how much of a natural environment a person takes in, thereby affecting well-being outcomes (Frumkin et al., 2017; Marselle et al., 2021). We therefore add to preference research on differences between the two groups by accounting for differences in potential well-being outcomes. Potential differences between groups are further important to account for as they could inform future forest management planning where conflicting demands and opinions may occur (Tyrväinen et al., 2003). Arguably, the general public is a large group of 'forest users' whose opinion and needs could be of interest for forest managers to account for in their decisions (Jensen, 1993).

The overall aim of the present study was to investigate how psychological restoration may be supported by forest characteristics, which are affected by forest management. This was done by (1) investigating mechanisms between perceived restorativeness and forest characteristics. Specifically, we included attributes of nature protected by legislation, namely beauty, diversity, naturalness and uniqueness, and evaluated their importance for psychological restoration. We additionally tested for (2) differences in the assessment of forest stands on these attributes between forestry experts and people from the general public. Based on the results of objectives (1) and (2), we predicted (3) how forest management that affects forest characteristics may impact psychological restoration today and in the future. To do so, we simulated the visual appearance of a typical German forest (Augsburg Western Forests) under various forest management regimes.

We hypothesize

H1. Increased perceived beauty, diversity and naturalness will positively predict perceived restorativeness of the forest stand.

H2. Increased forest diversity, as quantified by specific forest variables (e.g. the percentage of conifers), will increase perceived forest beauty.

H3. Participants from the general public will rate the perceived beauty, diversity, naturalness and uniqueness of forest stands differently from experts.

H4. Forest management regimes that increase forest diversity will increase higher perceived restorativeness in the future.

Finally, to cover all three attributes stated in the German Nature Conservation Act (beauty, diversity, uniqueness), we explore the relationship between perceived uniqueness and restorativeness and the relationship between variables related to forest diversity and perceived diversity, naturalness and uniqueness.

2 | METHODS

2.1 | Participants

In total, 318 forestry experts and 381 participants from the general public participated in an online survey in which they rated several forest pictures regarding beauty, diversity, naturalness, uniqueness and restorativeness. Only completed surveys were included in the final sample, resulting in 212 forestry experts (male: 173, female: 39) and 301 participants from the general public (male: 149, female: 152); see Table 1 for further descriptive statistics. We collected data from both forestry experts and participants from the general public to test for differences in the assessments between the two groups. Forestry experts located in Bavaria (where our case study, Augsburg Western Forests is located) were invited via email and people from the general public were recruited via a fieldwork agency. Inclusion criteria for the final public sample were (a) German place of residence, (b) at least 14 years old and (c) at least one forest visit in the past 12 months to increase the likelihood that participants could imagine the pictured forest stands. Additionally, to control for their ability to imagine the pictured forest stands, after the rating they self-reported how well they could imagine the forest stands on a scale from 1 = very well to 5 = not at all (mean = 2.22, SD = 0.76).

2.2 | Materials and measures used in the survey

2.2.1 | Forest stand pictures

To depict several variations of forest structure, we generated 40 pictures of managed (with thinning) and unmanaged (without thinning) forest stands. The depicted forest structures can be directly connected with forest variables stated in Supporting Information S2. These variables are typically considered in forestry, related to forest diversity (Biber et al., 2021; Zeller et al., 2023) and could easily be used to generate future scenarios within the methodological approach of the present paper. Because these forest variables are affected by how a forest is managed, we also generated common silvicultural treatments: 'Clear-cut in stripes', a shelterwood system and 'Thinning from below' (Figure 1). 'Clear-cut in stripes' and 'shelterwood' are types of forest thinnings used to introduce growth of new species. 'Thinning from below' removes intermediate trees while larger trees are left for further growth. The individual pictures (Figure 1, Columns 1 to 5) in each silvicultural category were generated by progressively varying the percentage of conifers. For 'Thinning from below' and forest stands without thinning, we have additionally generated three phases depicting the age/height

TABLE 1 Demographics and descriptive statistics of how participants from the general public and forestry experts rated perceived restorativeness indicators, perceived restorativeness and their self-reported ecological knowledge and nature connectedness.

Variable	General public		Forestry experts	
	Frequency	Percentage	Frequency	Percentage
Gender				
Female	152	50.5	39	18.4
Male	149	49.5	173	81.6
Level of education				
No degree	2	0.7	0	-
Lower secondary education	74	24.6	0	-
Higher secondary education	69	22.9	13	6.1
Vocational training degree	95	31.6	0	-
University degree	56	18.6	197	92.9
Other	5	1.7	2	0.9
	Mean	Standard deviation	Mean	Standard deviation
Age (years)	46.7	17.3	45.9	13.2
Forestry experience (years)	NA	NA	20.8	12.6
Perceived beauty[a]	4.6	1.6	4.3	1.5
Perceived diversity[a]	4.0	1.9	4.0	1.6
Perceived naturalness[a]	4.6	1.7	4.0	1.6
Perceived uniqueness[a]	4.2	1.7	4.0	1.5
Perceived restorativeness[a]	4.8	1.6	4.3	1.5
Ecological knowledge[b]	3.1	0.6	3.9	0.6
Nature connectedness (NR-6)[c]	3.7	0.8	4.1	0.6
Nature connectedness (INS)[c]	4.0	1.3	4.7	0.9
	r	*p*-value	*r*	*p*-value
Correlation NR-6–INS	0.6	<0.001	0.5	<0.001

[a]All perception variables (beauty, diversity, naturalness, uniqueness and restorativeness) were measured on 7-point bipolar scales with the positive connotation on the left and the negative connotation on the right.

[b]Self-reported ecological knowledge was measured on a 5-point scale with 1 = very low to 5 = very high.

[c]NR-6 was measured on a 5-point scale with higher scores indicating stronger connectedness to nature. INS was measured on a 6-point scale with higher scores indicating stronger connectedness to nature.

along the *Y*-axis. We decided not to include this for shelterwood and clear-cut in stripes since changes in age for shelterwood are very small and clear-cut in stripes would have been too complex to analyse.

2.2.2 | One-item perceived beauty, diversity, naturalness, uniqueness and restorativeness

Each variable was rated on a 7-point bipolar measure with the positive connotation on the left and the negative connotation on the right, leading to the following pairs of adjectives: beauty: beautiful versus ugly, diversity: diverse versus monotonous, naturalness: natural versus unnatural, uniqueness: special versus ordinary, restorativeness: restorative versus stressful. Similar approaches using bipolar items have been applied by several studies on nature perception and human well-being (Marselle et al., 2016; Simkin et al., 2021). While perceived restorativeness is commonly measured using the Perceived Restorativeness Scale (PRS, Hartig et al., 1997), we decided to also measure this item on a one-item bipolar scale to ensure an appropriate length of the survey. A similar approach was facilitated by Herzog et al. (2003), who developed a one-item question for the restorative potential of an environment, which has also been used in research on nature perception and restoration (Twedt et al., 2019).

2.2.3 | Nature connectedness

Nature connectedness was measured using the short version of the Nature Relatedness Scale (NR-6; Nisbet & Zelenski, 2013, based on the German translation by Kleespies et al., 2021) and the Inclusion

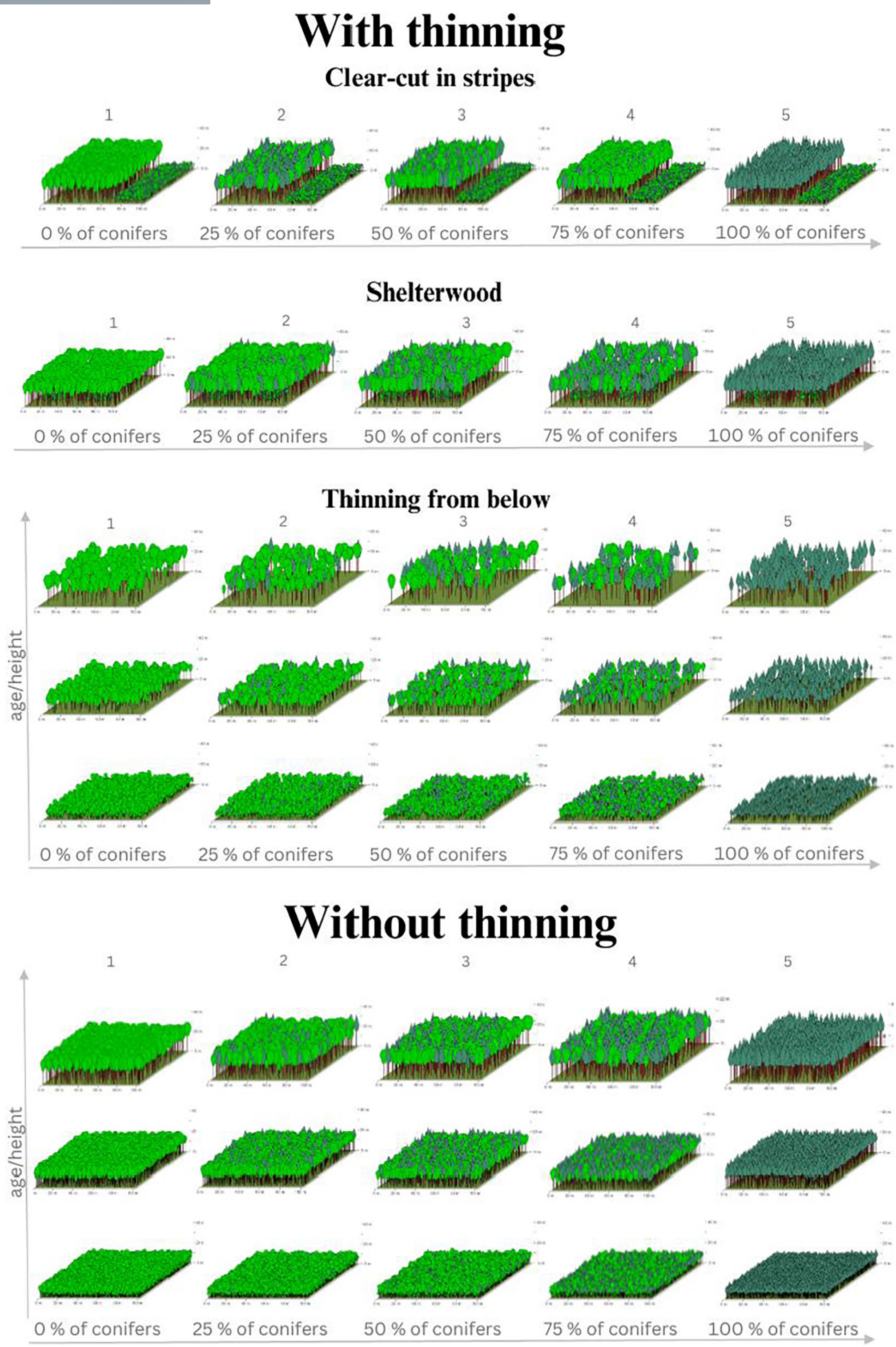

FIGURE 1 Forest stand pictures as shown one by one in the survey. The pictures depict the range of the variables described in Supporting Information S2. From left to right, the percentage of conifers increases (light green: deciduous trees; dark green: coniferous trees). For forest stand pictures with silvicultural treatments 'Thinning from below' and 'Without thinning', from bottom to top, the height/age of the trees increases.

of Nature in the Self Scale (INS; Schultz, 2002). Both measure nature connectedness in a similar manner (Tam, 2013; see also Nisbet & Zelenski, 2013) and are useful when survey space is limited. However, due to the one-item structure of INS, a calculation of reliability is not possible, and its graphical nature might be difficult to understand by participants (Tam, 2013). We therefore decided to also include NR-6, a 6-item scale using statements, where reliability analysis is possible.

2.2.4 | Ecological knowledge

Ecological knowledge was measured by one self-report question 'How would you rate your ecological knowledge?' and was measured on a 5-point scale (1 = very low and 5 = very high).

2.3 | Survey development and procedure

Using SosciSurvey, a German online survey tool, we conducted a survey containing all measures explained above. The survey was pre-tested to ensure technical functionality, coherence and feasibility. After actively accepting informed consent by clicking on the relevant option, in random order, participants rated each forest stand picture concerning perceived restorativeness and the four potential restorativeness indicators, namely perceived beauty, diversity, naturalness and uniqueness. While forestry experts rated the whole set of 40 forest stand pictures, participants from the general public rated a subset of 24 forest stand pictures to minimize dropout rates. Here, we chose to keep pure deciduous (Figure 1, Column 1) and pure coniferous forest stands (Figure 1, Column 5) across all types of silvicultural treatments (with thinning: clear-cut in stripes, shelterwood, thinning from below; without thinning). Additionally, we randomly showed one of the three pictures depicting mixed forest stands (see Figure 1, Columns 2–4) for each silvicultural treatment. All participants were instructed to view each picture for a moment and to give their first impression. They were instructed to imagine walking past the respective forest stand in their free time and were advised to evaluate each picture on its own rather than comparing the pictures. They were also instructed that each picture illustrates the type, number and height of trees as well as different forest management regimes. After rating the pictures, participants self-reported their ecological knowledge, nature connectedness, age, gender, level of education and the federal state of residence. Forestry experts additionally indicated their forestry experience (in years). There were no institutional requirements for ethical approval.

2.4 | Statistical modelling and selection

Using linear mixed effects modelling (LME), we developed a perceived restorativeness model based on forest variables related to forest diversity and restorativeness indicators (perceived beauty, diversity, naturalness and uniqueness); see Figure 2. Specifically, we fitted an LME for each of the four restorativeness indicators with all the explanatory forest variables included. Then, we fitted another LME model for perceived restorativeness with the four restorativeness indicators, perceived beauty, diversity, naturalness and uniqueness as the explanatory variables. To reveal potential differences between forestry experts and participants from the general public, we included the respondent group (forestry expert = 0 vs. general public = 1) as a factor variable in all LMEs, as well as the interactions between respondent group and each forest variable and restorativeness indicator, respectively.

Model selection for each of the restorativeness indicators was performed in two steps. First, we simplified the available variables with a preliminary selection based on a correlation analysis (Dormann et al., 2013). We dropped highly correlated variables ($r > |0.7|$), choosing variables that are visually most relevant and can best characterize forest structure, based on our expertise (see Supporting Information S3). For instance, the variation of tree heights correlated with the mean gap area. Because we expected the variation of tree heights to be more relevant for visual assessments and better depicts forest diversity, we dropped the mean gap area. This resulted in the following remaining forest variables, which were used as explanatory variables in the four LME models for restorativeness indicators (LME 1 to 4): percentage of conifers in the area ($share_{con}$), number of trees per hectare (N), mean diameter (d_q), coefficient of variation of tree heights (cv_h), skewness of the trees' diameter distribution ($skew_d$) and the relative canopy cover (Canopy cover). To ease the subsequent model selection, we fitted general additive mixed models (mgcv package, Wood, 2006), revealing preliminary non-linearities between restorativeness indicators and forest variables (Supporting Information S4). Based on this analysis, we included the respective variables as linear or quadratic terms in the LMEs; see Table 2. Finally, we applied an automated model selection on the resulting expressions from the two previous steps (LME 1 to 4) and on the general restorativeness expression (LME 5). We tested every possible combination of the predictor variables and selected the model with the lowest AIC (Akaike information criterion; Akaike, 1974) using the function 'dredge' in the R package MuMIn (Bartoń, 2022).

2.5 | Simulation of five scenarios of forest management and their effect on perceived restorativeness

To investigate how forest management may affect future perceived restorativeness and its individual indicators (perceived beauty, diversity, naturalness and uniqueness), we simulated five scenarios that express the currently broadly applied forest management regimes in Central Europe, namely Rotation forestry, Continuous cover forestry, Adaptation to climate change and Set-aside (Toraño Caicoya, Poschenrieder, et al., 2023). Specifically, we simulated how a typical German forestry landscape (Augsburg Western Forests) would develop in the future when applying these typical management regimes. We started our simulations into the future from detailed inventory data of Augsburg Western Forests from the Bavarian Forests state service and National forest inventory data for 2010, with a total of 6960 inventory points. Applying the fitted LME models based on participants' responses to the forest stand pictures shown in Figure 1, we next predicted how perceived restorativeness and its indicators might develop in the coming 100 years (in 5-year intervals) given the five scenarios of forest management. A summary of the management regimes can be found in Table 3 and more detailed in Supporting Information S1. The simulations of forest dynamics and management were conducted using the forest simulator SILVA (Pretzsch et al., 2002, 2008), which

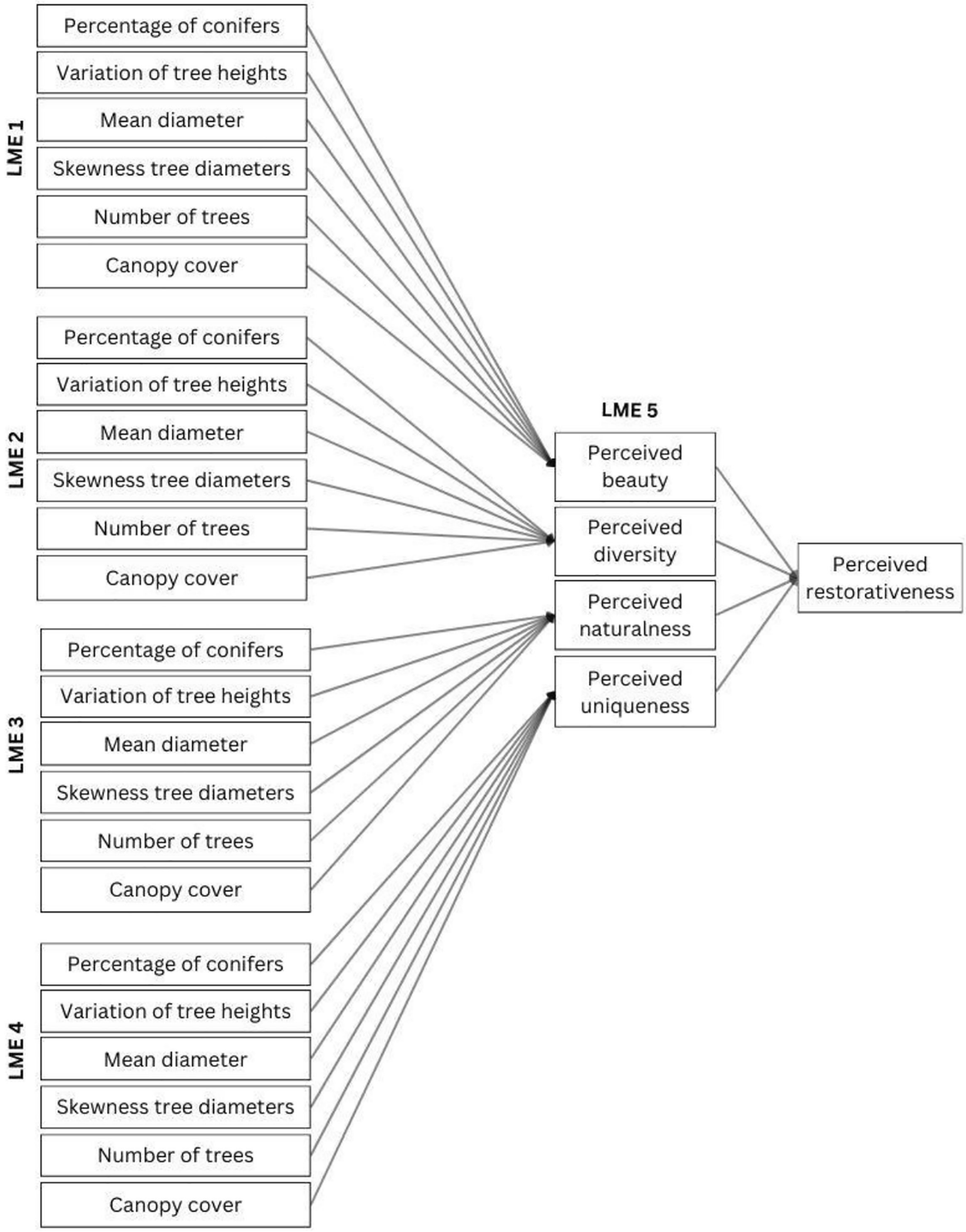

FIGURE 2 Modelling approach. LME1 to 4 model the relationships between the four restorativeness indicators (perceived beauty, diversity, naturalness and uniqueness) and the explanatory forest structure variables, and LME5 models the relationship between the perceived restorativeness and the restorativeness indicators.

has been developed to support practitioners in forest management. SILVA is based on a single-tree model that accounts for the distance between trees but is age-independent. SILVA has frequently been used for landscape-scale simulation of mixed and pure species stands containing central Europe's the most important tree species (Biber et al., 2020). More details about how SILVA simulates forest stand development can be found in Supporting Information S5. Since SILVA is a single-tree model, all the explanatory variables included in the models for restorativeness and its indicators can be derived from the simulated forest data for each simulation period. A conceptual figure depicting the study process can be found in Supporting Information S6.

2.5.1 | Augsburg Western Forests

Our case study region constituting simulation starting conditions is the Augsburg Western Forests region (48.34 N, 10.63 E). This region is located in the federal state of Bavaria, Southern Germany, to

TABLE 2 Descriptions of forest variables and how they were used in the four linear mixed effects modelling (LME) for the relationships between restorativeness indicators (perceived beauty, diversity, naturalness and uniqueness) and forest variables.

Variable abbreviation	Forest variable (unit)	Min	Max	Beauty[a]		Diversity[a]		Naturalness[a]		Uniqueness[a]	
$share_{con}$	Percentage of conifers in the area (%)	0	100	X	X^2	X	X^2	X	X^2	X	X^2
N	Number of trees per hectare (trees ha^{-1})	123	8983	X		X		X		X	
d_q	Quadratic mean diameter (cm)	5.9	40.7	X	X^2	X		X	X^2	X	
cv_h	Coefficient of variation of tree heights (nd)	0.1	0.8	X	X^2	X	X^2	X	X^2	X	X^2
$skew_d$	The skewness of the trees' diameter distribution (nd)	−0.2	1.7	X		X	X^2	X	X^2	X	
Canopy cover	Relative canopy cover (nd)	0.3	1.0	X	X^2	X		X		X	

[a]Variables were included either as a linear term (X) or also as a quadratic term ($X+X^2$) depending on results of the general additive mixed modelling (Supporting Information S4).

TABLE 3 Summary characteristics of the simulated management regimes; see Supporting Information S1 for more detail. Spruce stands for Norway spruce (*Picea* abies (L.) H. Karst), beech for European beech (*Fagus sylvatica* L.) and pine for Scots pine (*Pinus sylvestris L.*)

Management regime type[a]	Focus	Harvesting top height [m]			Management regime specifics
		Spruce-dominated	Beech-dominated	Pine-dominated	
Rotation forestry	Wood production, age class	30	30	30	Standard rotation forestry with thinnings from below and clear-cut
Rotation forestry (foreign species)	Intensified wood production, age class	33	30	30	Intensification of management with the promotion of fast-growing (foreign) species
Continuous cover forestry (CCF)	Continuous wood production structure	38	33	33	Selective thinnings and target diameter final cutting
Adaptation to climate change	Multifunctionality	32	25	28	Promote diversity, stability, continuity, converts to broadleaved dominated stands
Set-aside (SA)	Set-aside	NA	NA	NA	No thinning, no harvest

[a]Simulated forestry management regimes are currently broadly applied regimes in Central Europe (Toraño Caicoya, Poschenrieder, et al., 2023).

the West of the city of Augsburg. The highly managed area forms part of a 'Nature Park' (German: 'Naturpark'), a legally defined region with some degree of protection, environmentally friendly land use, and where services like recreation and positive effects on visiting people are very important. This is a strong argument for maintaining high multifunctionality and biodiversity, but the region is also among the most productive forest regions of Germany, where artificially established Norway spruce (*Picea abies*, L.) stands, widely planted in Bavaria after WWII, dominate the landscape (Table 4).

TABLE 4 Tree species distribution in the Augsburg Western Forests used for the scenario simulations.

Type	Volume [$m^3 ha^{-1}$]	Growth [$m^3 ha^{-1} year^{-1}$]	% of area
Pure conifer	428	12	55
Main conifer and >15% deciduous	348	11	20
Pure deciduous	225	5	12
Main deciduous and >15% conifer	278	7	9

3 | RESULTS

3.1 | Relationships between perceived restorativeness and perceived beauty, diversity, naturalness and uniqueness

Perceived beauty, diversity, naturalness, uniqueness and the respondent group variable (experts vs. general public) all positively and statistically significantly predicted perceived restorativeness. Beauty was the most important predictor, followed by respondent group, diversity, naturalness and uniqueness, confirming hypothesis H1. Moreover, the model indicated statistically significant interactions between respondent group and perceived beauty, diversity and naturalness (Table 5, Figure 3), confirming H3. For both groups, perceived restorativeness increased with perceived beauty, where less beautiful forest stands were judged to be more stressful, and more beautiful forest stands were perceived as more restorative. Interestingly, when participants from the general public perceived a

TABLE 5 Estimates of parameters (with standard errors) associated with explanatory variables (and the intercept and random effect) and interaction effects in the LME for perceived restorativeness. Respondent group is 0 if it is of type 'Expert' and 1 if it is of type 'General public'.

Predictor	Estimate	Standard error	*p*-value
Intercept	0.775	0.042	<0.001
Beauty	0.692	0.010	<0.001
Diversity	0.087	0.008	<0.001
Naturalness	0.034	0.008	<0.001
Uniqueness	0.023	0.006	<0.001
Respondent group [0,1]	0.474	0.008	<0.001
Beauty x Resp. group [0,1]	−0.136	0.014	<0.001
Diversity x Resp. group [0,1]	−0.069	0.010	<0.001
Naturalness x Resp. group [0,1]	0.149	0.012	<0.001
Random effect	**Standard deviation**	**Residual SD**	
Participant level	0.467	0.687	
R^2	0.778		

Note: Interaction effects between variables are expressed with 'x'.

forest stand to be ugly, that is, a beauty value of 1 from a maximum of 7, they still perceived it as less stressful than forestry experts. The more beautiful a forest stand was rated, the smaller was the difference in perceived restorativeness between forestry experts and participants from the general public. For the latter, the perceived restorativeness of a forest stand was independent of its perceived diversity, but they continuously gave higher restorativeness ratings than experts did. For forestry experts, perceived restorativeness slightly increased with perceived diversity, and the group differences decreased with increasing perceived diversity. Perceived restorativeness increased with perceived naturalness for participants from the general public, but for experts, it was unrelated to perceived naturalness. While uniqueness appeared statistically significant in our model, this variable only weakly predicted perceived restorativeness for both groups (Table 5, Figure 3).

3.2 | Relationships between perceived beauty, diversity, naturalness, uniqueness and forest variables

Mixed forest stands were perceived as most beautiful, diverse, natural and unique as indicated by high ratings at intermediate values of the forest variable 'percentage of conifers' (Table 6, Figure 4), confirming hypothesis H2. This was, to a lesser extent, also the case for perceived beauty, naturalness, and uniqueness and their relationship with the variation of tree heights, whereas perceived diversity showed a non-linear increase with the variation of tree heights (Table 6, Figure S7.1). The perceived diversity and perceived naturalness showed slight non-linear relationships with the skewness of the trees' diameter distribution (Table 6, Figure S7.2), while perceived beauty and uniqueness decreased with the skewness of the trees' diameter distribution (Table 6). Perceived beauty and naturalness showed a slight non-linear relationship with the mean diameter (Table 6, Figure S7.2), whereas perceived diversity and uniqueness increased with the mean diameter, but uniqueness was not significant (Table 6). In the relationship between perceived beauty and canopy cover, ratings were highest at intermediate values of this forest variable (Table 6, Figure S7.2), while perceived diversity, naturalness and uniqueness decreased with this variable. Perceived diversity, naturalness and uniqueness were significantly related to the number of trees (Table 6), whereas perceived beauty was not, and in both cases, the effect size was low and there was almost no effect visible.

Forestry experts and participants from the general public perceived forest stands differently in terms of beauty, diversity, naturalness and uniqueness, as judged by significant interaction terms in several of the LMEs (Table 6), confirming H3. Specifically, their perceived beauty, diversity, naturalness and uniqueness differed depending on the percentage of conifers, the skewness of the trees' diameter distribution and the canopy cover. However, similarities also emerged. For example, both forestry experts and participants from the general public perceived mixed forest stands as most beautiful, diverse, natural and unique, but the latter generally gave higher ratings for each attribute (perceived beauty, diversity, naturalness and uniqueness) and the difference between the two groups increased with the percentage of conifers. Both groups perceived forest stands with 40%–50% conifers as most beautiful, while forest stands with 100% conifers were perceived as the least beautiful. Deciduous forest stands were perceived as less beautiful than mixed stands but more beautiful than coniferous stands. The relationships between the percentage of conifers and perceived diversity, naturalness and uniqueness were very similar: Mixed forest stands were evaluated as most diverse, natural, and unique by both groups. However, forestry experts perceived forest stands with 25%–30% of conifers as most natural while participants from the general public again rated forest stands with 50% of conifers as most natural. A similar pattern applied for perceived uniqueness, where forestry experts rated forest stands with 30% of conifers as most unique, while participants from the general public rated forest stands with 40%–50% of conifers as most unique (Figure 4).

3.3 | Future predictions given different forest management regimes

Based on projections with the models of how participants from the general public and experts viewed the relationships between restorativeness indicators and forest variables, Set-aside, where all management activities are abandoned and only natural mortality takes place, reached the highest values for both experts and the general

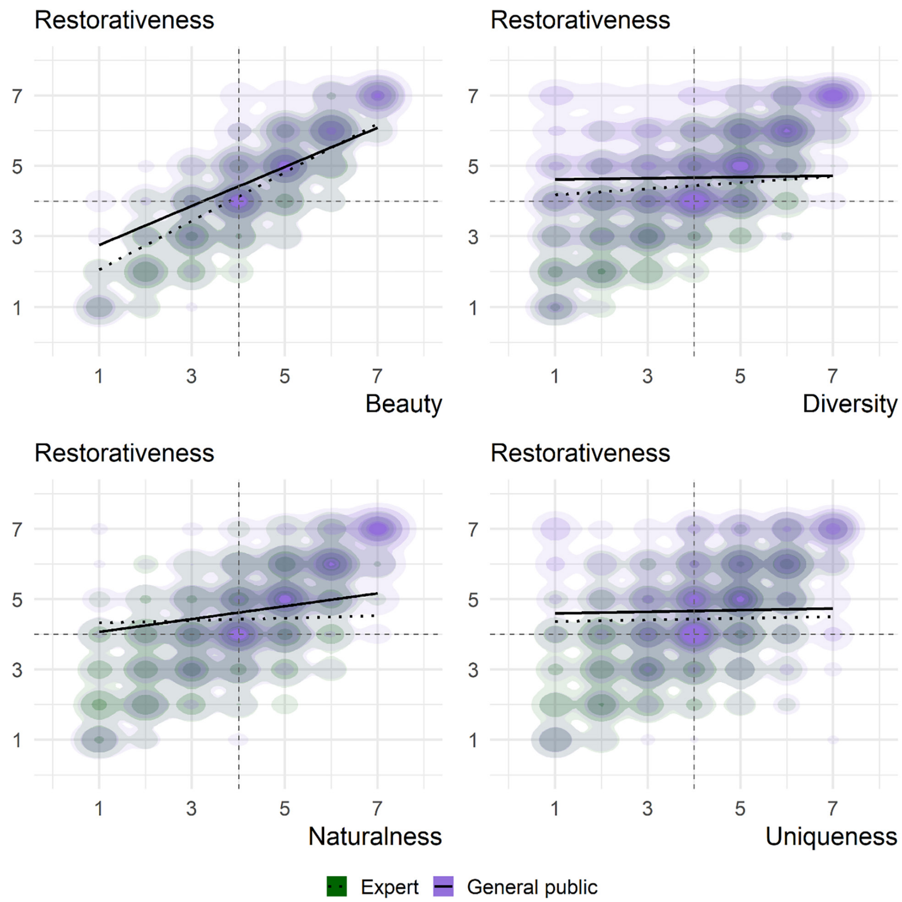

FIGURE 3 Relationships between how forestry experts ($N=212$) and participants from the general public ($N=301$) viewed the relationship between perceived restorativeness and the four indicators of restorativeness. For model details (estimates, R^2, p-values); see Table 5. All variables were measured on a 7-point bipolar scale, for example, 1 = beautiful, 7 = ugly. The dashed line represents the middle of the bipolar scale, for example, neither beautiful nor ugly. The 2-dimensional histogram shows the scatter density of the original data.

public. This scenario is followed by Adaptation forestry, a diverse management regime that promotes vertical structures and species mixtures. For perceived naturalness and diversity, the scenario Rotation (Foreign Species), a very production-oriented regime with fast-growing foreign species, leads to higher levels than Adaptation forestry around 2070. Rotation forestry, without planting foreign species, and CCF, the standard continues cover regime, lead to the lowest future levels for all indicators. Uniqueness showed the lowest future variation in all scenarios. For the regimes usually leading to high levels of forest diversity (Set-aside, Adaptation forestry and CCF), we observed early indicator increases until 2030. After this point, the indicators remained stable with Set-aside and Adaptation forestry while declining with CCF. The indicators showed slight changes during the simulation period with less diverse oriented managements (Rotation and Rotation with foreign species).

The most diverse scenarios achieved the highest final levels of perceived restorativeness for both respondent groups, thereby confirming H4 (Figure 6). Specifically, Set-aside led to the highest future levels of restorativeness. In the coming decades, the same holds true when managing them to be resilient against climate change (Adaptation forestry) or applying Continuous cover forestry. However, for the latter, after 2030, a decline in perceived restorativeness was projected due to a period of management transformation that may lead to a less diverse phase in comparison to the Rotation forestry regimes. These inferences are made by combining the five models, going from projected forest conditions given by different management scenarios via indicators of restorativeness (Figure 5) to the projection of the future perceived restorativeness (Figure 6).

4 | DISCUSSION

The overall aim of the present study was to investigate how psychological restoration may be supported by forest characteristics. For this purpose, we asked forestry experts and people from the general public to rate forest stand pictures on attributes of nature protected by legislation, which could also be beneficial for restoration. We found that all attributes, namely the perceived beauty, diversity, naturalness and uniqueness of a forest stand predicted perceived restorativeness, but beauty was most important. Evaluations significantly differed between forestry experts and the general public,

TABLE 6 Estimates of parameters (with standard errors, SE) associated with explanatory variables (and the intercept and random effect) and interaction effects in the LME for perceived beauty, diversity, naturalness and uniqueness. Respondent group is 0 if it is of type 'Expert' and 1 if it is of type 'General Public'.

	Beauty		Diversity		Naturalness		Uniqueness	
Predictor	**Estimate (SE)**		**Estimate (SE)**		**Estimate (SE)**		**Estimate (SE)**	
Intercept	1.75 (0.179)***		2.07 (0.146)***		4.02 (0.163)***		4.18 (0.139)***	
% of conifers	0.038 (0.001)***		0.058 (0.001)***		0.024 (0.001)***		0.028 (0.001)***	
% of conifers^2	-4.80×10^{-4} (0.000)***		-7.04×10^{-4} (0.000)***		4.44×10^{-4} (0.000)***		-4.23×10^{-4} (0.000)***	
Skewness tree diameters	−0.557 (0.051)***		1.34 (0.103)***		0.752 (0.106)***		−0.268 (0.053)***	
Skewness tree diameters^2	—		−0.789 (0.047)***		−0.556 (0.049)***		—	
Mean diameter	0.039 (0.006)***		0.023 (0.003)***		−0.026 (0.007)***		4.61×10^{-3} (0.003)	
Mean diameter^2	-5.49×10^{-4} (0.000)***		—		6.70×10^{-4} (0.000)***		—	
Variation tree heights	4.53 (0.319)***		8.41 (0.341)***		6.72 (0.337)***		3.98 (0.340)***	
Variation tree heights^2	−5.74 (0.379)***		−9.25 (0.422)***		−8.19 (0.416)***		−3.87 (0.411)***	
Number of trees	—		-1.74×10^{-4} (0.000)***		-1.32×10^{-4} (0.000)***		-6.20×10^{-5} (0.000)***	
Canopy cover	7.88 (0.463)***		−0.482 (0.069)***		−0.346 (0.070)***		−0.776 (0.067)***	
Canopy cover^2	−6.63 (0.342)***		—		—		—	
Resp. group [0,1]	−0.650 (0.135)***		−1.52 (0.111)***		−0.918 (0.119)***		−1.21 (0.143)***	
% conifers x resp.group [0,1]	0.010 (0.000)***		8.81×10^{-3} (0.001)***		0.018 (0.001)***		0.013 (0.000)***	
Skewness tree diameters x resp.group [0,1]	0.237 (0.061)**		0.488 (0.050)***		0.209 (0.005)***		0.190 (0.069)**	
Mean diameter x resp.group [0,1]	−0.019 (0.002)***		—		—		−0.015 (0.003)***	
Variation tree heights x resp. group [0,1]	0.250 (0.104)*		0.352 (0.087)***		—		0.806 (0.116)***	
Canopy cover x resp.group [0,1]	1.31 (0.078)***		1.52 (0.083)***		1.02 (0.081)***		1.51 (0.087)***	
Random effect	**Standard deviation**	**Resid. SD**	**Standard deviation**	**Resid. SD**	**Standard deviation**	**Resid. SD**	**Standard deviation**	**Resid. SD**
Participant level	0.87	1.09	0.75	1.21	0.90	1.19	0.80	1.22
R^2	0.43		0.47		0.44		0.36	

Note: Interaction effects between variables are expressed with 'x'.

*$p<0.05$. **$p<0.01$. ***$p<0.001$.

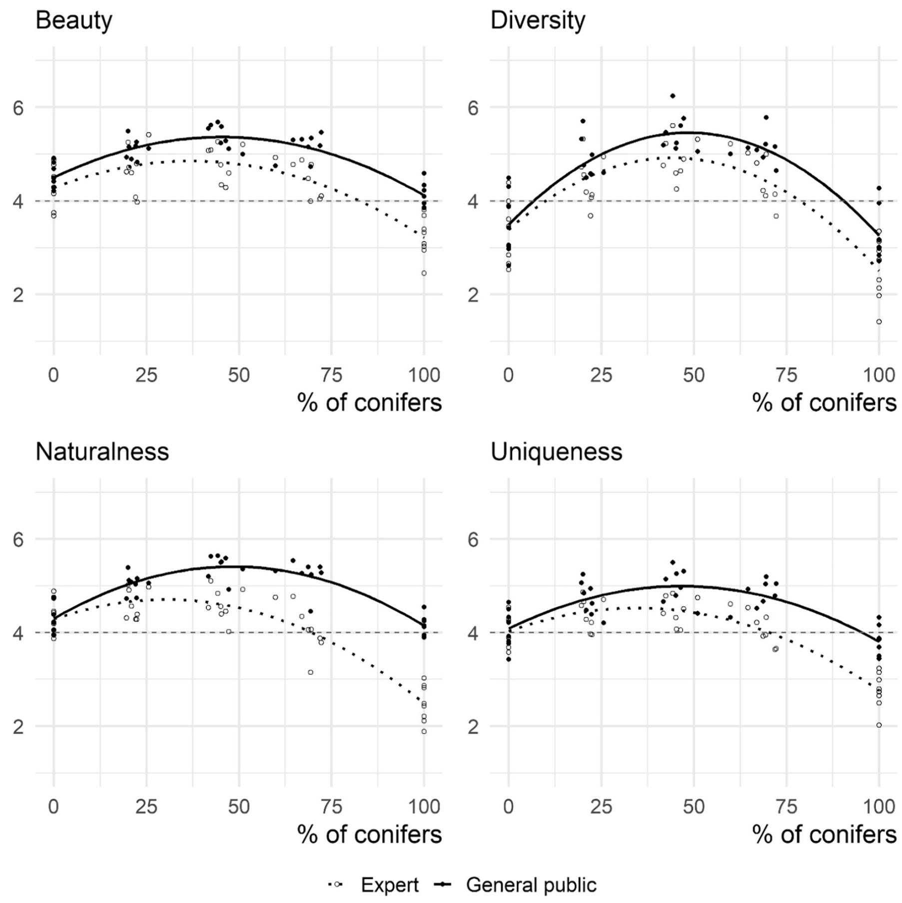

FIGURE 4 Relationships between how forestry experts (N = 212) and participants from the general public (N = 301) viewed the four indicators of restorativeness and the percentage of conifers. For model details (estimates, R^2, p-values); see Table 6. All variables were measured on a 7-point bipolar scale, for example, 1 = beautiful, 7 = ugly. The dashed line represents the middle of the bipolar scale, for example, neither beautiful nor ugly.

but similarities were also discovered. For instance, mixed forest stands were evaluated as most beautiful by both groups, but people from the general public gave higher ratings than forestry experts. Because forest characteristics are heavily impacted by which forest management is applied, based on the survey results, we predicted the future perceived restorativeness of forest stands depending on which forest management is applied. Our simulations indicated that setting-aside forest, which also benefits biodiversity conservation, reaches the highest restorativeness today and in the future.

4.1 | Perceived restorativeness, its indicators and forest conditions

We found that perceived beauty, diversity and naturalness might act as positive predictors of perceived restorativeness, confirming Hypothesis H1. Out of these, perceived beauty appeared to be the best predictor of perceived restorativeness. Perceived diversity, naturalness and uniqueness appeared to be significant as well, although the strength of the relationship was weaker. These findings replicate previous research that also revealed perceived beauty as the main predictor for perceived restorativeness (Simkin et al., 2021; Twedt et al., 2019). That perceived diversity appears as moderately linked with perceived restorativeness can also be regarded as in line with previous findings, suggesting this attribute to be an important factor for restoration (Aerts et al., 2018; see also, e.g. Dallimer et al., 2012; Fuller et al., 2007; Hoyle et al., 2017; Marselle et al., 2016; Simkin et al., 2021). Perceived naturalness is commonly regarded an important quality for restoration and perceived restorativeness (e.g. Grahn & Stigsdotter, 2010; Stoltz et al., 2016). Perceived uniqueness had the lowest power to predict perceived restorativeness. Indeed, none of the theories regarding nature-based restoration, including Attention Restoration Theory (Kaplan, 1995), Stress Reduction Theory (Ulrich, 1983, 1993) nor the Calm and Connection Theory (Grahn et al., 2021), suggest perceived uniqueness of the environment as key to support restoration. In the present study, uniqueness was operationalized using a bipolar scale, ranging from 'ordinary' to 'special'. As included in the German Nature Conservation Act, uniqueness is a more specified term in the sense of 'special characteristics' of a certain area, which can only be evaluated with more detailed background information and the location of the forest stands (Roth, 2006). Our operationalization may thus not have

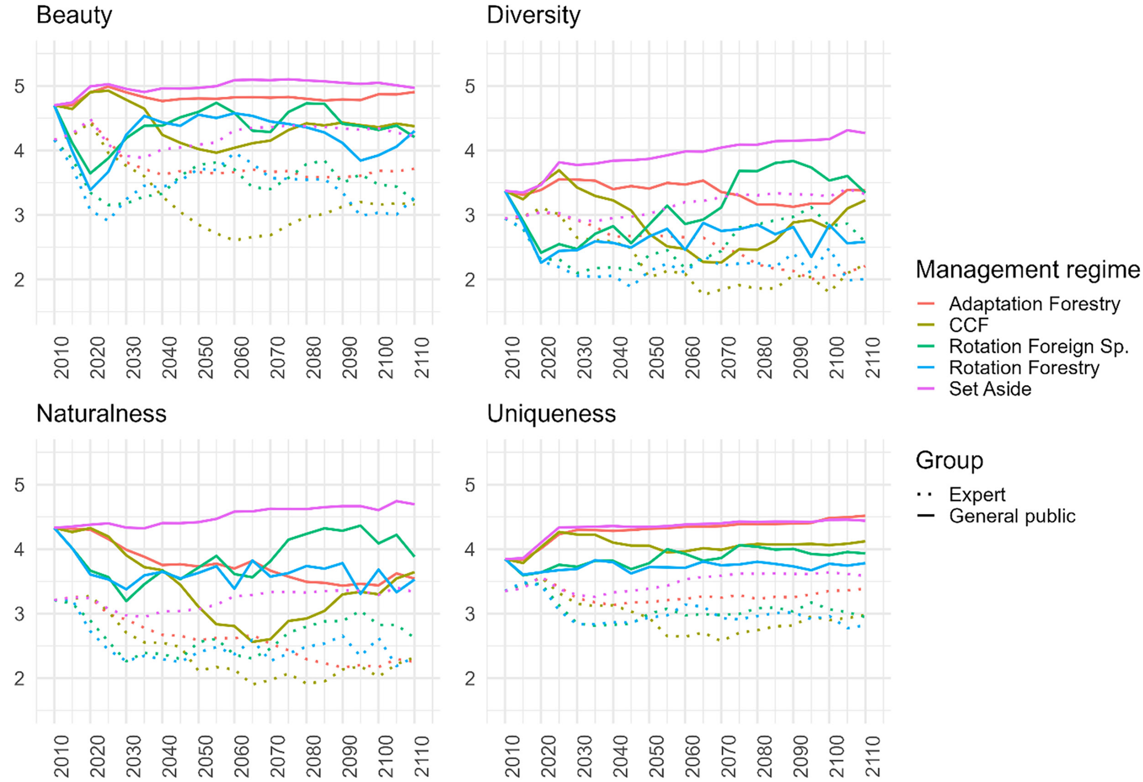

FIGURE 5 Future development of the indicators of restorativeness for five simulated management regimes based on ratings of forestry experts (N = 212) and participants from the general public (N = 301). Simulations were initialized with the inventory data from 6960 representative plots of the case Augsburg Western Forests.

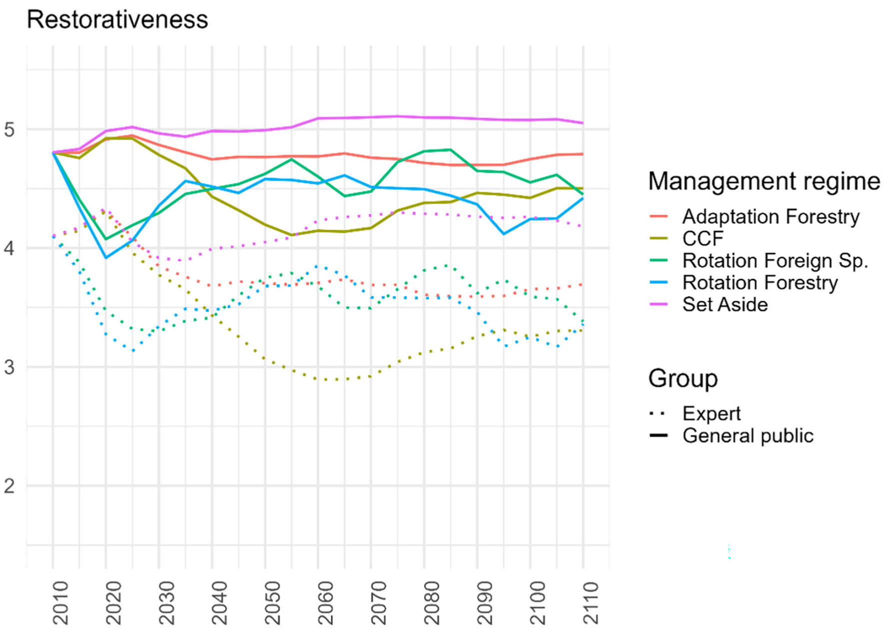

FIGURE 6 Development of the perceived restorativeness for six simulated management regimes and predicted using models based on ratings of forestry experts (N = 212) and participants from the general public (N = 301). Simulations were initialized with the inventory data from 6960 representative plots of the case Augsburg Western Forests.

measured the exact meaning of the German Nature Conservation Act. However, as it was statistically significant, we decided to keep it in the model as a more general variable. It would be interesting to investigate uniqueness across forest stands because the presence of multiple unique forest stands could add up to a diverse environment on a landscape level and thus cater for diverse preferences or needs in the population (Filyushkina et al., 2017), for example, recreation, physical and social activities or education purposes. It has also been suggested that people with a high level of stress may restore better in more uniform settings (Grahn & Stigsdotter, 2010, Stoltz, 2022), a need that could also be met with different forest stands on landscape level. While we have focused on potential restorative effects on stand level, future research could thus focus on other demands on landscape level. The underlying model could also be extended by, for instance, actual health outcomes, thereby allowing a more detailed and accurate picture that could lead to more robust conclusions about present and future forests' restorativeness.

We found that mixed forest stands were perceived as most beautiful, while coniferous forest stands were perceived as least beautiful, with deciduous forests in between. Thus, our hypothesized relationship between perceived beauty and variables related to forest diversity (H2) could be confirmed for the percentage of conifers. This is in line with previous results from landscape preference studies indicating that mixed forest stands are perceived as most beautiful or preferred for recreational purposes (Ebenberger & Arnberger, 2019; Filyushkina et al., 2017; Füger et al., 2021; Giergiczny et al., 2015). It may be surprising that diverse forests in terms of conifers and deciduous trees were rated as most beautiful (our most important predictor for restorativeness), but perceived diversity only weakly predicted restorativeness. The reason could be that we depicted diversity also through tree sizes, age and height. Possibly, this was more difficult to assess whereby participants rated diverse stands as more beautiful but were not conscious of diversity itself.

4.2 | Differences in the perception of forestry experts and participants from the general public

Forestry experts and participants from the general public gave different ratings, but similarities also emerged. More specifically, participants from the general public almost always rated the forest stands as more beautiful, diverse, natural and unique than forestry experts did. However, the pattern, for instance, for the percentage of conifers was very similar, that is, mixed forests were rated as most beautiful by both groups. Moreover, both experts and the general public gave higher ratings for perceived restorativeness the more beautiful the forest stand was perceived. Possibly, the main reason for the higher ratings from participants by the general public compared with experts could be that forests are work environments for the experts and recreational environments for the participants from the general public. This may lead experts to evaluate more based on their ecological or wood production knowledge, leading to different evaluations (Daniel, 2001; Tyrväinen et al., 2003). The rating differences could also stem from the possibility that computer-generated forest stand illustrations may be assessed differently than real-world forest stands, especially by forestry experts compared with people from the general public. Silvennoinen et al. (2022) found photo ratings to be a good method to investigate the attractiveness of forest stands with a simple structure but suggest 3D illustrations to be needed for more complex forest structures. However, in their study, neither forestry profession nor whether participants found the rating difficult affected the fit between photo ratings and field assessments. Additionally, in our study, people from the general public stated that they were able to imagine the illustrated forest stands. It is also worth mentioning that similar methods, such as photographs (e.g. Silvennoinen et al., 2001) or drawings (Filyushkina et al., 2017; Giergiczny et al., 2015), are often used for preference studies. While computer-generated forest stand illustrations certainly do not resemble actual nature experience, they allow better control of possible confounding variables such as light conditions (Filyushkina et al., 2017). They are therefore especially suitable when the variation or possible influence of certain forest variables need to be controlled. Our design facilitated a binary distinction (experts vs. general public) and descriptively included ecological knowledge and nature connectedness due to their potential influence on nature perception and well-being outcomes. Future research could disentangle the effects of ecological knowledge and nature connectedness by including these variables as predictors for restoration.

4.3 | Future perceived restorativeness given different forest management

We show that setting-aside forest without management should lead to the highest perceived restorativeness, following a stable trajectory into the future. This was mainly due to its high predicted perceived beauty, but also naturalness, and diversity. However, to also satisfy wood production demands a management regime like Adaptation forestry, which further aims to mimic naturally looking forests with higher diversity in species and tree dimensions, offers an alternative, with the second highest predicted perceived restorativeness. This management regime also had high perceived beauty, diversity and uniqueness, although it did not lead to such high perceived naturalness, especially towards the end of the century. Management regimes that follow traditional intensive silviculture (Rotation forestry) projected the lowest perceived restorativeness, mainly due to lower perceived beauty. However, we found that also CCF led to lower perceived beauty towards the end of the century. Specifically, CCF led to similar perceived beauty, but its diversity and naturalness were projected to decrease more than in Rotation Forestry, especially compared with the Rotation Forestry variation intensified with foreign species (Douglas fir). The reason for the decrease is that CCF applied here, typically intensive single-tree management, tends to develop into rather homogenous pure stands, especially in spruce-dominated and highly productive regions as the Augsburg Western Forests. We therefore found it curious that Rotation forestry with foreign species generally projected higher future perceived restorativeness than CCF. This could be explained by the introduction of Douglas fir, which, due to its fast growth, quickly introduces noticeable diversity into spruce stands, and then maintain apparent density with big trees contributing to the perceived naturalness and beauty. It should be noted that our future projections are based on present assessments of experts and people from the general public. However, forest preferences have been found to be relatively stable over time (Gundersen & Frivold, 2008; Jensen, 1999). Moreover, as forests are slowly changing systems, simulations over several decades are needed to establish how forest management actions today will finally play out. Forests serve many different demands, and it is likely that different forest management regimes are needed to cater these demands. For example, a recent study of Nordic boreal forests (Stoltz et al., 2024) suggests a combination of CCF and Set-aside to provide the strongest support for salutogenic functions. More nuanced knowledge is needed to provide evidence-based insights that could inform forest management decisions on landscape level.

5 | CONCLUSION

Based on our model and simulations, applying no management (Set-aside) would lead to the highest perceived restorativeness over the course of 100 years. However, to also satisfy demands for timber, Adaptation forestry could be a good alternative also leading to high levels of perceived restorativeness. Based on our results, it may be recommendable to increase forest diversity in areas with a high number of visitors. Arguably, a high number of visitors could also disturb some individuals and people with a high level of stress may actually restore better in less diverse forests (Stoltz, 2022). Therefore, more nuanced knowledge on different demands and how those could be included in forest management decisions is needed to provide evidence-based recommendations on applying different forest management regimes on landscape level.

AUTHOR CONTRIBUTIONS

Kilian Ramisch, Michael Suda and Birgit M. Probst conceived the ideas and designed the methodology for the survey. Astor Toraño Caicoya, Torben Hilmers and Tord Snäll conceived the ideas and designed the methodology for the simulations. Birgit M. Probst and Michael Suda collected the data. Birgit M. Probst and Astor Toraño Caicoya analysed the survey data. Astor Toraño Caicoya and Torben Hilmers conducted the simulations. Birgit M. Probst led the writing and revision of the manuscript. Patrik Grahn and Jonathan Stoltz contributed mainly to the introduction and discussion of the study. All authors have participated in the interpretation and discussion of the study as well as in writing and revising of the manuscript and have approved the final version of the manuscript for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicting interests to declare that are relevant to the content of this article.

DATA AVAILABILITY STATEMENT

To ensure complete confidentiality as promised in the informed consent provided to all participants, we are unable to make the data publicly available.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supporting Information S1. Description of forest management regimes.

Table S1.1. Rotation forestry in many production-oriented forest systems is characterized by a prolonged thinning phase, followed by a clear cut.

Table S1.2. Rotation forestry foreign species (rotation forestry with additional underplanting of Douglas fir in all stand types and of spruce-like conifers and in stands dominated by broadleaved species, a prolonged thinning phase is followed by a clear cut).

Table S1.3. Continuous cover forestry, characterized by rare interventions that focus on largest trees only and occasionally remove competitors.

Table S1.4. Adaptation to Climate Change (a continuous cover forestry concept typical for German state forestry that aims at conversion into a continuous cover regime with high species diversity and a spatially inhomogeneous distribution of tree sizes).

Supporting Information S2. Forest variables visible in the forest stand pictures.

Supporting Information S3. Correlation Matrix of forest variables.

Figure S3. Correlation Matrix of forest variables.

Supporting Information S4. Non-linear mixed models (GAMMs) for preliminary model variable selection.

Figure S4.1. Generalized additive mixed models for the relationships between perceived beauty and forest variables.

Figure S4.2. Generalized additive mixed models for the relationships between perceived diversity and forest variables.

Figure S4.3. Generalized additive mixed models for the relationships between perceived naturalness and forest variables.

Figure S4.4. Generalized additive mixed models for the relationships between perceived uniqueness and forest variables.

Supporting Information S5. SILVA core function and functionality.

Supporting Information S6. Conceptual figure of research process.

Supporting Information S7. Additional plots of significant quadratic terms in models 1 to 4 and their relationship with restorativeness indicators (perceived beauty, diversity, naturalness, uniqueness).

Figure S7.1. Relationships between perceptions of forestry experts and participants from the general public of four indicators of restorativeness and the variation of tree heights. For model details see, Table 6 in the manuscript.

Figure S7.2. Relationships between perceptions of forestry experts and participants from the general publicof indicators of restorativeness and the skewness calculated for tree diameters, mean diameter and the relative canopy cover. For model details see, Table 6 in the manuscript.

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