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Comparison of Ecosystem Services from Mixed and Monospecific Forests in Southwest Germany: A Survey on Public Perception

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Abstract: Scientific studies have shown that mixed forests of silver fir (*Abies alba* Mill.) and European beech (*Fagus sylvatica* L.) provide higher ecosystem services than monospecific forests. Mixed forests are known for their high resilience to climate change impacts and superior biodiversity compared to monospecific forests. Despite this superiority, the transformation from monospecific to mixed forests can meet socio-technical challenges that are manifested in dissent or even in conflicts. The integration of stakeholders and citizens plays a key role in analyzing their perceptions and views of forest transformation. Their knowledge is required to co-design and implement socially acceptable options and pathways to increase the share of mixed forests. Based on a survey in Southwest Germany, we analyzed stakeholders' and citizens' perceptions of ecosystem services of monospecific and mixed forests of silver fir and beech. The findings show that people believe that mixed forests provide better cultural, regulating, and supporting ecosystem services than monospecific forests. However, provisioning services were perceived as being equally or even better provided by monospecific forests. The assumed abundance of old trees and the feelings of pleasantness especially influenced the superior perception of ecosystem services provided by mixed forests. The results indicate that there is public support for the transformation of monospecific silver fir and beech forests into mixed forests in Southwest Germany.

Keywords: mixed forests; monospecific forests; online questionnaire survey; ecosystem services; public perception; stepwise regression

1. Introduction

The demands on forest ecosystem services have increased due to rapid human population growth and the depletion of natural resources, consequently threatening the continuous supply of ecosystem services. In addition, climate change impacts are limiting or even reducing the capability of forest ecosystems to meet human needs [1], and they are challenging forest management globally. Along with the rise of the global average surface temperature, there is a high risk of increase in extreme events such as heat waves, floods, and droughts [2,3]. Forests are believed to be especially prone to climate change impacts due to the long life span of trees, as well as the low migration rates of various species inhabiting forest ecosystems [4,5]. An alteration in climatic conditions will affect species distribution, local species composition, and consequently forest structure. These changes will influence forest biodiversity and ecosystem functions, thus representing a challenge to the provision of ecosystem services, on which human well-being depends [6,7]. Hence, there is a strong need to develop possible adaptation strategies for forest ecosystems to increase the resilience of forests against climate change, while enhancing

forest functions and the provision of ecosystem services [4,8]. As a result, incorporating adaptation and mitigation strategies in forest management have become policy goals for countries around the world. For example, in 2015, the United Nations set the Sustainable Development Goals (SDGs) for the "2030 Agenda for Sustainable Development" to promote sustainable forest management and increase resilience [8]. In particular, Goal 13, "Climate Action" and Goal 15, "Life on Land" aim to combat the negative impacts of climate change, and to protect and promote the sustainable use of forests and other terrestrial ecosystems, as well as to stop biodiversity loss and land degradation [9].

Scientific forestry in Germany started in the 18th century when large-scale forest restoration was undertaken on landscapes that were degraded by overexploitation and the industrial revolution. Monocultures of conifers (e.g., Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H. Karst.)) were the main choice at that time. However, since the beginning of German forestry, researchers have debated whether mixed forests can deliver better or preferred ecosystem services than monospecific forests [10]. Nadrowski, et al. [11] reviewed studies on this topic and found that generally tree species diversity is positively related to forest productivity. Gamfeldt, et al. [7] showed that species-rich forests have positive relationships with various ecosystem services, including biomass production, carbon storage, supply of berries, and game stock. Furthermore, diversity at a landscape level is expected to buffer insect outbreaks, fire, storms, and other disturbances related to climate change [8].

In Germany, adaptation strategies for forest management towards climate change are already being implemented, even though they remain at an early stage, and approaches vary between locations [8,12]. German forestry is shifting from a timber-production enterprise towards more comprehensive, multifunctional sustainable forest management with an emphasis on social and ecological objectives. Furthermore, there is an increasing focus on achieving self-sustaining forest functions and processes, as well as enhancing the provision of ecosystem services [6,10,13].

In the European Union, the protection of ecosystem services is promoted through the EU 2020 Biodiversity Strategy, which recognizes ecosystem services and biodiversity as being fundamental for human life, wealth, economics, and wellbeing [14]. Because of their importance to human wellbeing, it is important to assess public perceptions on this topic. Public participation is considered as important for sustainable forest management. Only through the involvement of people in decision-making processes, can the needs, targets, and opinions of stakeholders be addressed to achieve social sustainability and to develop effective forest management policies [15,16]. Against this background, our study aims to contribute insights into the preferences, beliefs, and perceptions of people about ecosystem services from different forest management practices (e.g., mixed vs. monospecific) in order to understand how these services contribute to human wellbeing. Such studies are still rare in Central Europe, with the exception of some recent studies in Belgium and Poland [10,17].

Since mixed forests have shown higher stability and resistance against extreme events such as storm and drought, mixing tree species is assumed to be an adaptive measure to increase the resilience of forests [8,13]. Higher diversity in mixed forest stands has also demonstrated the provision of regulating ecosystem services, such as protection against fire or pathogen damage. Although European beech is a natural species in Southwest Germany, it is becoming susceptible to drought-induced die-back as the climate warms [18]. Recent studies found that co-occurring tree species reduce the drought effect on beech trees by facilitative interactions [19,20]. The reason for this is that flat and shallow-rooting silver fir and deep-rooting beech trees increase water use efficiency in trees by the hydraulic redistribution of water, thus reducing drought stress in beech trees [21].

Some Federal states of Germany are promoting mixed forests because there is growing scientific evidence on the benefits of mixed forests. This change has an impact on not only forest management and economics, but also on the landscape and nature experience and usage and recreation habits. Even though the feasibility of mixed forests has been proven and despite their contribution to transform forests into more sustainable and resilient forests, their implementation is meeting challenges that are manifested, inter alia, in dissents and even conflicts in adapting new management plans by some

stakeholder groups, respectively, foresters and private forest owners. This is not surprising, since such changes are an intervention in the living environment of citizens [22], which are addressing the following challenges:

1. The need for and the planned location for forest transformation is controversial.
2. The opportunities and benefits, disadvantages or even risks of this transformation, and the specific locations of transformation are often unevenly distributed.
3. There is a discrepancy between the perspectives of experts and those affected, such as citizens, especially with regard to the balance between advantages and disadvantages, opportunities and risks.
4. There is criticism of the decision-making process itself, including insufficient (formal, but also informal) public participation [23].

One reason for dissent is that foresters believe that monospecific forests are easier to manage using highly-mechanized technologies and processes. On the other hand, Tian et al. 2015 [24] conducted a study about factors influencing non-industrial private landowners in Tennessee, United States, and found out that non-industrial private landowners are genuinely interested in managing their forests for the provision of ecosystem services. Differences in their interest depend on socio-demographic factors, ownership and management characteristics, as well as financial incentives [24]. However, the knowledge stocks in this research area, which can be found in literature, are very low. Especially for Germany, no studies on this specific topic have been conducted. The presented research study aims to fill this gap by assessing the perceptions of people belonging to different stakeholder groups on ecosystem services provided by mixed and monospecific forests of fir and beech in Southwest Germany by the means of an online questionnaire survey. The study is guided by the following research questions:

1. What are respondents' preferences when comparing mixed and monospecific forests of fir and beech?
2. What are respondents' perceptions on ecosystem services provided by mixed forests compared to monospecific forests of fir and beech?
3. How are respondents' perceptions influenced by social profiles, such as age and profession, as well as their habits and preferences?

2. Materials and Methods

2.1. The Study Region: Southwest Germany

The focus of the current study is on the hilly region of the Black Forest in the state of Baden-Württemberg, in Southwest Germany; this region has the natural potential for mixed forests of silver fir and European beech. In the study region, strong deforestation and forest conversion of mixed forests dates back around 2000 years. In the 19th century, Norway spruce (*Picea abies* (L.) H. Karst.) was planted to restore the forests in Southwest Germany. From then on, monospecific coniferous stands dominated the forest landscape [25]. Since the catastrophic winter storms (i.e., extratropical cyclones) of the 1990s, foresters have tried to convert these coniferous monocultures into mixed stands through re-introducing broadleaf tree species [18]. In 2004, forest districts in the Black Forest region started to convert even-aged monocultures of conifers into a mixed, structurally rich, uneven-aged forest [26–28]. The European beech is playing an important role in this forest development strategy, as it belongs to the potential natural vegetation of Southwest Germany [18,29]. The success of this mixed forest becomes apparent through the increase of beech dominated forest cover from under 18% to 22% between 1987 and 2012. The objective for beech-dominated mixed forest in publicly owned woodlands in Baden-Württemberg is to further increase the share to 30% by 2100 [30–32]. According to the third German National Forest Inventory in 2012, the total forest area in Germany covers 11.4 Mio ha [33]. After Bavaria, the federal state of Baden-Württemberg has the second largest forest area of Germany,

with forest cover of 1.4 ha, or 38% of the total area [33]. The forests in our study region belong to the state of Baden-Württemberg, which comprises on average 53% and 47% coniferous and deciduous forests, respectively [32]. Norway spruce accounts for the largest share among the dominant tree species (34%), followed by beech (22%), silver fir (8%), and oak (7%). Maple and ash (together 8%) are also important species in ad-mixtures. The aim of forest management is to create European beech and silver fir forest mixtures in appropriate sites to cope with the impacts from droughts and storms [34]. The distribution of European beech and silver fir trees overlaps in Southwest Germany, and they can naturally co-occur at sites above 500 m of elevation (Figure 1).

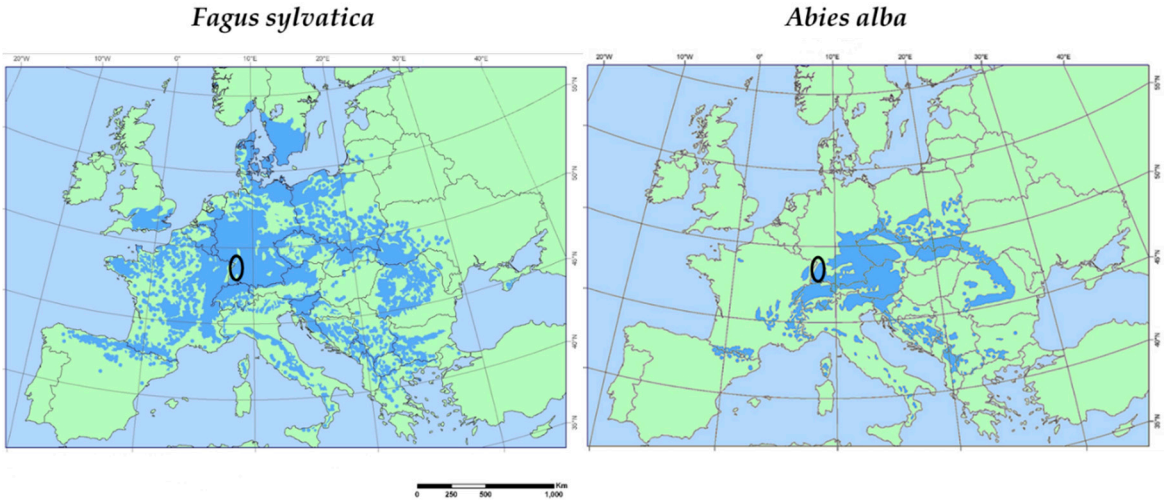

Figure 1. Distribution range of European beech (**left**) and silver fir (**right**) [35]. Note that in Southwest Germany (marked in oval), the natural distribution of these two species overlaps.

2.2. Design of the Questionnaire and Finding Potential Respondents

Our sampling design was based on a combination of different non-probability sampling methods. The first step of the survey design was a review of how to undertake stakeholder selection and promote participation in the survey. The findings of the review were used to develop a stakeholder analysis for the state of Baden-Württemberg and to identify stakeholders, which are relevant and important for our study and representing different views, needs, and interests on forests. This approach is similar to the procedure applied by Paletto et al. and Balest et al. [36,37], and it is a way of judgmental sampling, as it is based on the selection of specific groups of the population, which are of particular interest to the researcher [38]. The result of the review was a comprehensive list of key stakeholders representing different organizations and institutions, such as forestry organizations, environmental associations, timber/forest industries, universities, research institutions, tourism and recreation associations, political parties, and local councils. The list was made by the means of internet research and through consultation.

In the second step, a web-based questionnaire was designed using the platform www.umfrageonline.de [39] to perform the online survey. We decided to use web-based questionnaires for our survey, given the many advantages of this method such as: the possibility of reaching a high number of people in a short period of time, accessibility to individuals in distant locations, fast response, and low cost. Another advantage is that data entry is automated, enabling higher data accuracy, so that possible errors in data entry can be avoided. One of the disadvantages of using online questionnaire surveys is that not all segments of the population can be reached. However, most of our target stakeholders belonged to segments of the population that normally use the internet as a mean of communication and information [37,40]. Invitations to participate in the questionnaire were sent via e-mail to previously selected key stakeholders. These persons were asked to forward the questionnaires to other stakeholders from their field of interest. By this, we used

the "snowballing" process, another non-probability sampling method, where selected persons get in touch with other potential stakeholders [10,40]. The third step was to share and distribute the link to the survey on social media, in particular on Twitter and Facebook, in order to reach citizens in Southwest Germany. These were ordinary citizens; however, options were provided in the survey to report their links to appropriate stakeholder groups [38]. We asked neutral questions to avoid response bias. The stakeholders and citizens who participated in our survey are hereinafter referred to as 'respondents'.

The respondents were categorized into six key stakeholder groups:

1. foresters and people working in forest industries;
2. policy makers;
3. researchers;
4. people working in Non-Governmental Organizations (NGOs);
5. people associated with tourism and recreation clubs (hiking, cycling, horse riding, hunting etc.);
6. students; and
7. others (e.g., teachers, engineers etc.).

The web-based questionnaire comprised three main sections:

1. respondents' social profile;
2. respondents' preferences between mixed and monospecific forests of silver fir and beech; and
3. respondents' perceptions of ecosystem services provided by mixed versus monospecific forests of silver fir and beech.

It is an accepted fact that people's perceptions are formed differently according to their beliefs, experiences, cultural expectations, motivations and attitudes [10]. To elicit how these factors have an influence on respondents' expectations of forest ecosystem services, information about the social profile of the respondents such as profession, age, gender, and preferred recreational activities were gathered for each respondent.

The understanding of ecosystem services and the structure adopted to cluster the different ecosystem services for the questionnaire is based on the work of the Millennium Ecosystem Assessment (MEA). According to MEA, ecosystem services are "benefits that people obtain from ecosystems and which contribute to human well-being" [1] and can be classified into four main categories:

1. supporting ecosystem services (nutrient cycling, biodiversity, resistance against pathogens and illnesses, etc.);
2. regulating ecosystem services (carbon sequestration, filtration of pollutants, soil stability against erosion, etc.);
3. provisioning ecosystem services (provision of food, fuel, wood, game stock, financial return, etc.); and, . . .
4. cultural ecosystem services (recreation, tourism, aesthetic experience, etc.) [1].

2.2.1. Respondents' Social Profile

The first part of the survey comprised questions about respondents' gender, age, education level, profession, and whether that profession was related to forests or forest ownership. Data about respondents' habits, such as frequency of visits to the forest, and preferred recreational activities were also collected. The respondents were clustered into four age classes: (1) 18 to 25, (2) 26 to 40, (3) 41 to 60, and (4) over 60 years old. Respondents were asked to rank their three most preferred forest activities out of 13 recreational activities offered. After completion of the survey, those activities were grouped into nine main activities for further data analysis (Table 1).

Table 1. Simplification of recreational activities addressed in the survey for data analysis.

Detailed Activities (Questionnaire)	Simplified Activities (Data Analysis)
Hiking, walking, jogging	Hiking
Cycling and mountain biking	Cycling
Horse riding	Horse riding
Hunting	Hunting
Collecting mushrooms, wild garlic and other plants; wild honey and fruits (Non Wood Forest Products or NWFPs)	Collecting plants and mushrooms (NWFP)
Collecting firewood	Collecting firewood
Picnicking	Picnicking
Observing plants and animals	Observing plants and animals
Meditating, having a spiritual experience	Meditating

2.2.2. Respondents' Preferences between Mixed and Monospecific Forests of Fir and Beech

The second part of the survey comprised questions about respondents' preferences between mixed and monospecific forests of European beech and silver fir. For the respondents´ information, brief species descriptions of European beech and silver fir, and the following definitions of mixed forests and monospecific forests were provided:

(1) Mixed forest: "A forested area with at least two predominant genus of trees, where each genus accounts for at least 10% of the stand area" [41].
(2) Monospecific forest: "A forested area, where the dominant tree genus accounts for more than 90% of the stand area" [41].

In addition, images of single beech and fir trees, monospecific beech and fir forests, as well as of a mixed forest, were included with the survey to avoid different "virtual" imaginations of monospecific and mixed forests by the survey participants.

In order to investigate the perceived pleasantness of mixed forests in comparison to monospecific forests, participants were asked from which forest landscape they experience a greater pleasant feeling. They were also asked if they believe that old trees can be found in mixed forests than in monospecific forests of silver fir and beech. This question is based on the assumption that people like the appearance of old and big trees, and that they might have the impression that these trees are more frequent in mixed forests than monospecific forests. We also investigated whether respondents have a stronger "feeling at home" in monospecific forests of silver fir or beech compared to mixed forests.

2.2.3. Respondents' Perceptions of Ecosystem Services Provided by Mixed Forests Compared to Monospecific Forests of Fir and Beech

In the third part of the survey respondents were asked to give their opinions of 18 different ecosystem services (Table 2) based on MEA [1] and Carnol et al. [10]. In doing so they had to rank their answers on a 5-point Likert scale [42] with the following interpretation: (1) fully agree, (2) rather agree, (3) neither agree nor disagree, (4) rather disagree, and (5) fully disagree. In addition, the respondents had the option of "I don't know" (D.K.). The D.K. option allows the respondents to express their lack of awareness for any specific question [43].

Table 2. List of ecosystem services in the survey to be ranked by respondents.

Type of Ecosystem Services	Name of Ecosystem Services	Key Variables/Keywords for the Ecosystem Services Which were Selected for Survey
Provisioning	Timber yield	timber yield
	Biomass	biomass productivity
	Profitability	monetary/economical profitability
	Hunting	availability of wild game populations
	Non-wood forest products	opportunities to collect mushrooms, fruits, wild garlic, honey, etc.
Cultural	Recreation	recreation possibilities and allow spiritual experience
	Tourism	attractiveness for tourism
	Education	contribution to education
	Observing plant and wildlife	opportunities for observation of plants and animals
Regulating	Pollution Control	capacities to control pollution and keep the air clean and thus to improve human health
	Water retention	potential to increase water retention capacity (ability of the soil, to retain water)
	Erosion	function for soil protection against erosion
	Carbon storage	higher ability for carbon storage
Supporting	Resilience to climate change Biodiversity	capacity to return to its original state after disturbances caused by climate change
	Biodiversity	diversity of habitats, plant & animal species
	Resistance to storms	resistance against storm events
	Resistance to droughts	tolerance against drought periods
	Resistance to diseases	protection against diseases and pests (e.g., insects, fungi, etc.).

Cultural services are defined as "ecosystem contributions to the non-material benefits (e.g., capabilities and experiences) that arise from human–ecosystem relationships" [44]. Studies have shown that societies become less dependent on provisioning (e.g., firewood) with higher economic development, while they become more dependent on cultural services [45,46]. The European Union strategy recognizes cultural services as having the utmost importance, as they represent complex relationships between ecosystems and humans. Despite their importance, cultural services have been rarely assessed in scientific literature; apart from tourism and recreation [46]. One reason might due to the difficulty of quantifying their importance [46,47]. Current publications of cultural ecosystem services have mainly focused on economic, as well as biophysical assessments. However, the socio-cultural aspects have not been thoroughly evaluated [47]. By means of this research, we want to contribute to further assess perception on cultural ecosystem services.

Supporting services are known as enabling services as they provide the requirements for the generation of other ecosystem services, including biomass production, soil formation and retention, as well as the provisioning of habitats. Thus, the well-being of humans is a result of supporting services provided by provisioning, regulating, and cultural ecosystem services [45]. Resilience is usually not considered as an ecosystem service, although we included it in the category of supporting ecosystem services, together with resistance to drought, storm, and diseases. However, the assessment of respondents' perceptions of the resilience of forest ecosystems was crucial for our findings, as maintaining forest resilience is an important climate change adaptation and mitigation mechanism [48].

2.3. Data Analysis

The survey resulted in 520 valid responses, which were included in the analysis. Duplications of responses were prevented by ensuring that the questionnaire link could only be used once in an electronic device. The survey portal automatically saved the responses and created a database in Microsoft Excel for statistical analysis.

The data analysis was undertaken in two steps. First, a set of descriptive analyses were carried out on respondents' preferred activities in forests and their perceptions of ecosystem services, addressing the respondents' preferences when comparing mixed and monospecific forests of fir and beech, and their perceptions of the ecosystem services provided by monospecific and mixed forests.

Second, variance and regression analyses were carried out to investigate the relations between social profiles and people's preferences for ecosystem services between silver fir-beech mixed forests and monospecific forests of the respective species. Therefore, we averaged the Likert values to four major categories of supporting, regulation, cultural, and provisioning services. The average value of Likert scores was used as a dependent variable in each category. We had 10 categorical and binary explanatory variables:

1. stakeholder groups
2. level of education
3. resident of the Black Forest region
4. gender
5. age
6. frequency of forest visit
7. forest ownership
8. pleasantness,
9. feeling at home (in German "Heimatgefühl")
10. frequency of big and old trees.

The regression analysis was carried out with the "Automatic Linear Modelling" (ALM) version 20 of the recent IBM-SPSS program described by Yang [49] and in the web guidelines for SPSS.20 [50]. This enabled us to use a feature to select the categorical binary variables after performing a collinearity analysis through a stepwise regression approach. The regressions excluded the auto

correlated variables. Akaike's Information Criterion was used for the selection of final outputs. The parameter estimates were used to measure the significance of the relationship between the target and the explanatory variables. The ALM package also calculated a parameter called the "predictor's importance", which ranges from 0 to 1, with higher values indicating higher significance. The importance of the predictor or explanatory variable is the residual sum of squares with the predictor removed from the model, normalized so that the importance values sum to 1. It allowed us to rank the explanatory variables based on their statistical importance. The parameter estimates of each explanatory variable of a regression output generated were used to plot for better visualization by the package "plotrix" of R Statistical Program [51,52]. The confidence interval of parameter estimate should not touch 0 for a significant effect. The negative value of the parameter estimate denotes a negative effect, whereas the positive value of the parameter estimate would mean a positive effect.

3. Results

3.1. Respondents' Social Profiles

Out of 520 respondents, 38% were female and 62% male. Most of the respondents were 18 to 40 years old, representing 64% of the total sample (Figure 2a). About 62% of the respondents had attained a university degree (Figure 2b). Researchers (27%) represented the largest stakeholder group, followed by forestry professionals (25%) and students (18%). Respondents working in policy and decision-making (Figure 2c), NGOs, tourism, and recreation organizations were nearly equally represented. Almost 13% of the respondents belonged to the group of private forest owners. Around 60% of the respondents lived in the Black Forest area. A majority of the respondents (80%) visited the forest all year round and did not have a specific seasonal preference (Figure 2d). The frequency of forest visits was nearly equal (i.e., 28%) between people who visited forests weekly and monthly. Close to 38% of respondents visited forests daily or on multiple days in every week, whereas only 6% visited forests less often.

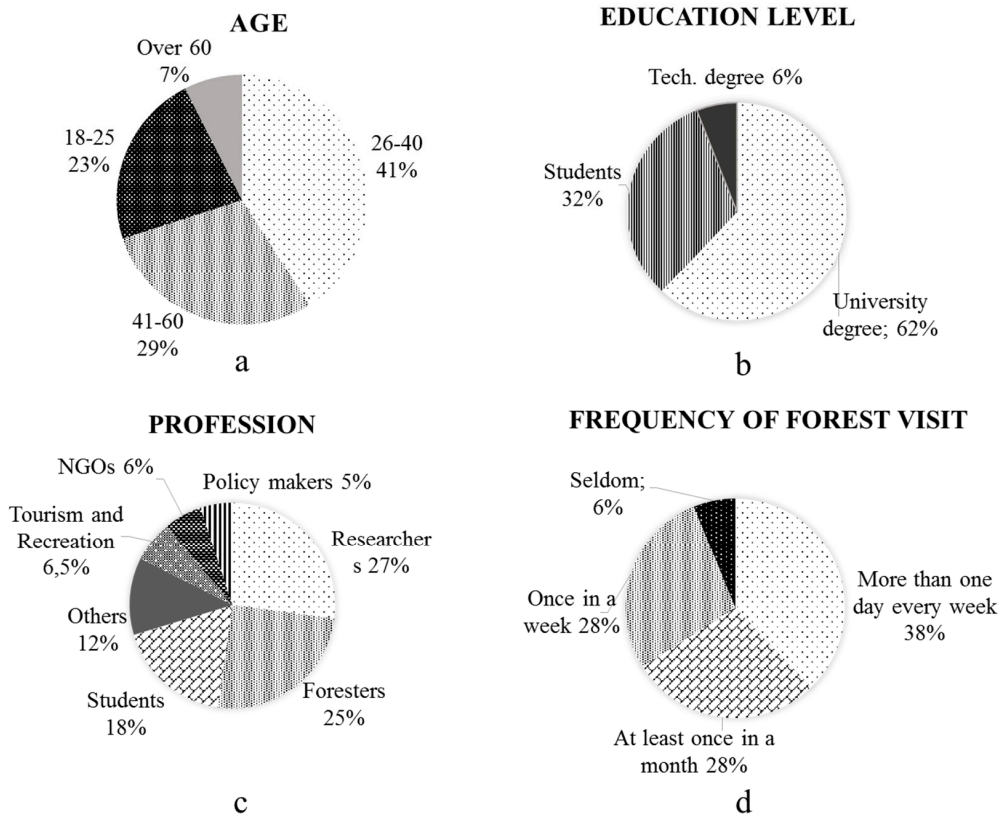

Figure 2. Respondents' social profile and their frequency of forest visits, (**a**) AGE, (**b**) education level, (**c**) profession, (**d**) frequency of forest visit.

3.2. Respondents' Preferences on Recreational Activities

Each respondent could choose up to three preferred recreational activities. The percentage values were calculated from the 1134 preferences reported by 520 respondents. The recreational activity preferred by nearly all respondents (96%) was hiking, suggesting that a large percentage of people go to the forest for recreation (Figure 3). Observing plants and wildlife, and collecting mushrooms, gathering firewood, picnicking, bicycling, and hunting were other popular recreational activities. However, activities such as meditation and horse riding were only preferred by a small percentage (<20%) of the respondents.

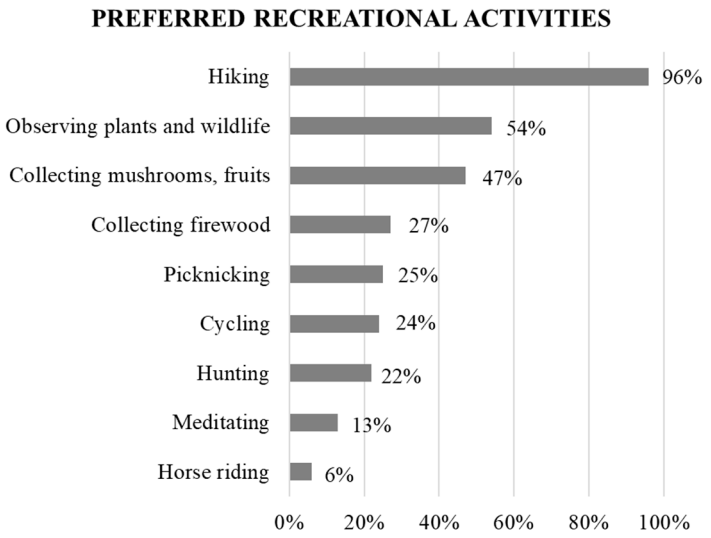

Figure 3. Preferred recreational activities of the respondents. Each respondent could choose up to three preferred recreational activities. The percentage values were calculated from the 1134 preferences reported by 520 respondents.

Nearly 80% of respondents perceived that the pleasantness of mixed silver fir-beech forests was greater than for monospecific forests (Figure 4). 46% of the respondents believed that old and big trees are more likely to be found in silver fir-beech mixed forests rather than in monospecific forests. 59% of respondents had a higher 'feeling at home' in silver fir-beech mixed forests, whereas 24% and 17% of the respondents feel more at home in beech and fir monospecific forests, respectively.

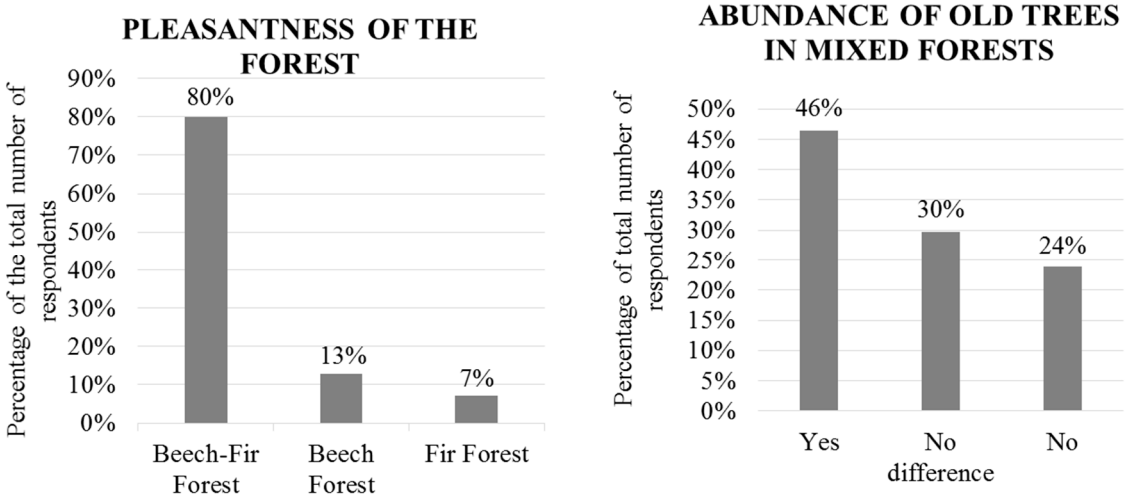

Figure 4. Respondents' (N = 520) feelings on the pleasantness of the forest and the abundance of old and big trees in mixed forests compared to monospecific forests.

3.3. Respondents' Perceptions of Ecosystem Services

Respondents' perceptions of ecosystem services were assessed by average score on the Likert scale, which ranged from 1 to 5. Scores close to 1 denoted that respondents strongly believe that a certain ecosystem service is higher in mixed forests than monospecific forests. In contrast, scores close to 5 represented the opposite perception. Sometimes, respondents selected the "I don't know (D.K.)" option for certain questions. For sake of clarity and understanding, we did not include those responses in our analysis (Figure 5). Nevertheless, we analyzed the proportion of respondents who gave "I don't know" responses for each ecosystem service (Figure 6).

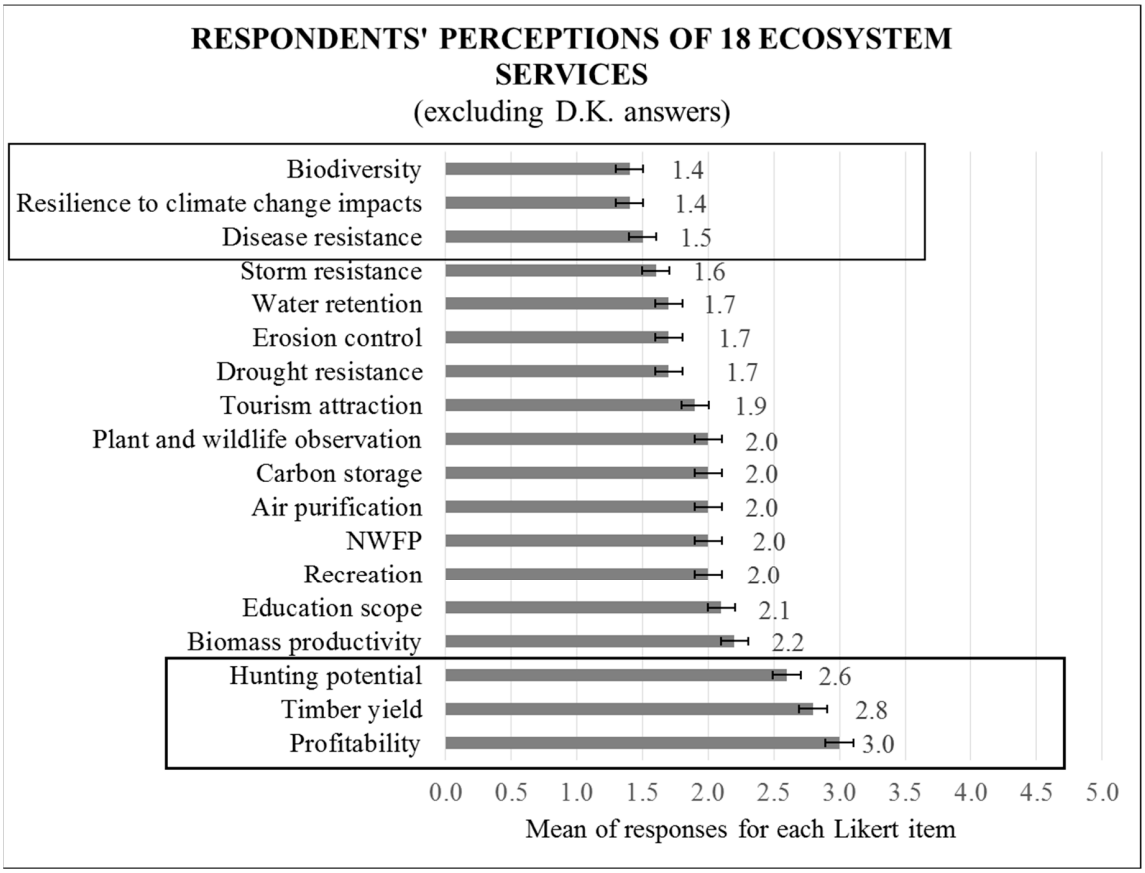

Figure 5. Average perceptions of different ecosystem services provided by mixed forests compared to monospecific forests. The perceptions were measured for 18 ecosystem services (i.e., Likert items) on a 5-point scale (1 = strongly agree, 5 = strongly disagree), excluding D.K. (I don't know) answers.

Overall, respondents perceived that mixed forests provide higher ecosystem services than monospecific forests of fir and beech; 15 out of 18 ecosystem services had an average score from 1.4 to 2.2. Some ecosystem services (biodiversity, resilience to climate change, and resistance to diseases) were perceived as being higher in mixed than in monospecific forests; the Likert scores for those ecosystem services ranged between 1.4 and 1.5 (Figure 5). Conversely, respondents believed that ecosystem services such as profitability, timber yield, and hunting potential were higher in monospecific forests than in mixed forests; average Likert scores for those services ranged from 2.6 to 3.

"I don't know" (D.K.) responses varied between ecosystem services. Respondents had a high awareness of ecosystem services such as biodiversity, plant and wildlife observation, recreation, and resilience; only 2–6% of respondents did not know about these (Figure 6). In contrast, respondents had a lower level of awareness about ecosystem services such as hunting potential, profitability, and timber yield: 17–30% of respondents did not have a clear opinion on those services.

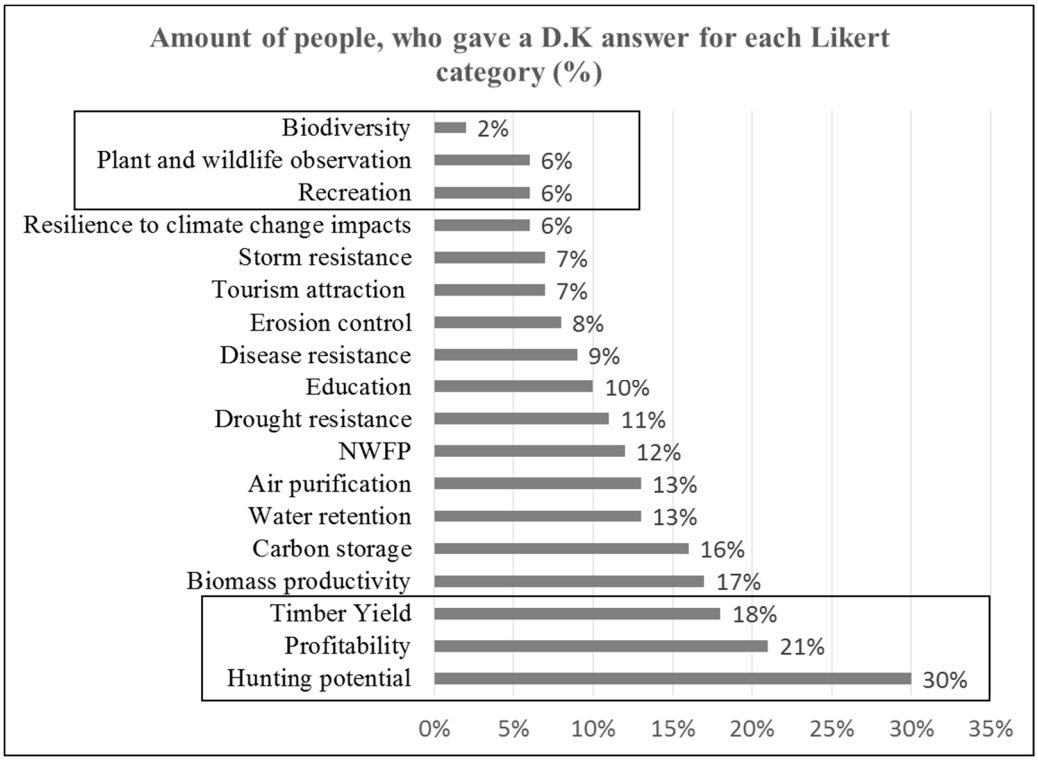

Figure 6. Percentage of respondents who provided "I don't know" (D.K.) responses for each ecosystem service or Likert item. Note that the percentage was calculated from the total number of respondents for each Likert item related to the other response categories (1 = fully agree to 5 = fully disagree). For instance, only 2.3% of the respondents provided a D.K response regarding biodiversity related to the other response categories.

3.4. Variation in Respondents' Perceptions between Supporting, Regulating, Cultural, and Provisioning Ecosystem Services in Relation to Social Profiles and Preferences

We averaged the Likert scores of 18 ecosystem services into four classes of supporting, regulating, cultural, and provisioning services, and plotted them against 10 social profiles and preferences (Table 3, Figure 7). We found a general trend of higher positive perceptions (i.e., lower Likert values) of supporting services; followed by regulating, cultural and provisioning services. This trend was consistent among all 10 variables although had some variations. The analyses of variances (ANOVAs) showed that all four types of ecosystem services varied significantly within the different classes of social variables such as education level, and age, as well as by preferences on pleasantness, feeling at home, and the frequency of old and big trees in forests (Table 3, Figure 7). The responses varied significantly between male and female respondents for the provisioning, cultural, and regulating services, but not for the supporting services. The responses for provisioning and cultural services varied between the different stakeholder groups. The perceptions of cultural ecosystem services varied by residency, frequency of forest visits, and forest ownership (Table 3, Figure 7).

Table 3. Analyses of variances (ANOVAs) of average Likert scores for different types of ecosystem services within 10 variables related to social profiles and preferences of respondents. Numbers in bold are significant responses.

Social Profiles and Preferences of Respondents	Type of Ecosystem Services	F-Value	*p*-Value
Stakeholder groups	Provisioning	2.45	**0.0242**
	Cultural	7.06	**0.0000**
	Regulating	1.62	0.1396
	Supporting	1.02	0.4095
Level of education	Provisioning	5.21	**0.0057**
	Cultural	9.20	**0.0001**
	Regulating	6.76	**0.0013**
	Supporting	3.83	**0.0224**
Residence	Provisioning	0.15	0.6960
	Cultural	4.91	**0.0272**
	Regulating	1.32	0.2518
	Supporting	0.53	0.4657
Gender	Provisioning	12.25	**0.0005**
	Cultural	25.35	**0.0000**
	Regulating	7.64	**0.0059**
	Supporting	1.94	0.1647
Age	Provisioning	5.12	**0.0017**
	Cultural	4.41	**0.0045**
	Regulating	3.71	**0.0116**
	Supporting	3.10	**0.0263**
Frequency of forest visits	Provisioning	0.61	0.6105
	Cultural	3.47	**0.0161**
	Regulating	1.22	0.3002
	Supporting	0.89	0.4464
Forest ownership	Provisioning	0.70	0.4039
	Cultural	9.06	**0.0027**
	Regulating	2.01	0.1566
	Supporting	7.52	0.0063
Pleasantness of forest	Provisioning	4.46	**0.0121**
	Cultural	17.96	**0.0000**
	Regulating	13.08	**0.0000**
	Supporting	6.40	**0.0018**
Feeling at home	Provisioning	8.85	**0.0002**
	Cultural	22.94	**0.0000**
	Regulating	9.99	**0.0001**
	Supporting	4.30	**0.0141**
Frequency of old and big trees	Provisioning	13.79	**0.0000**
	Cultural	40.14	**0.0000**
	Regulating	35.10	**0.0000**
	Supporting	23.86	**0.0000**

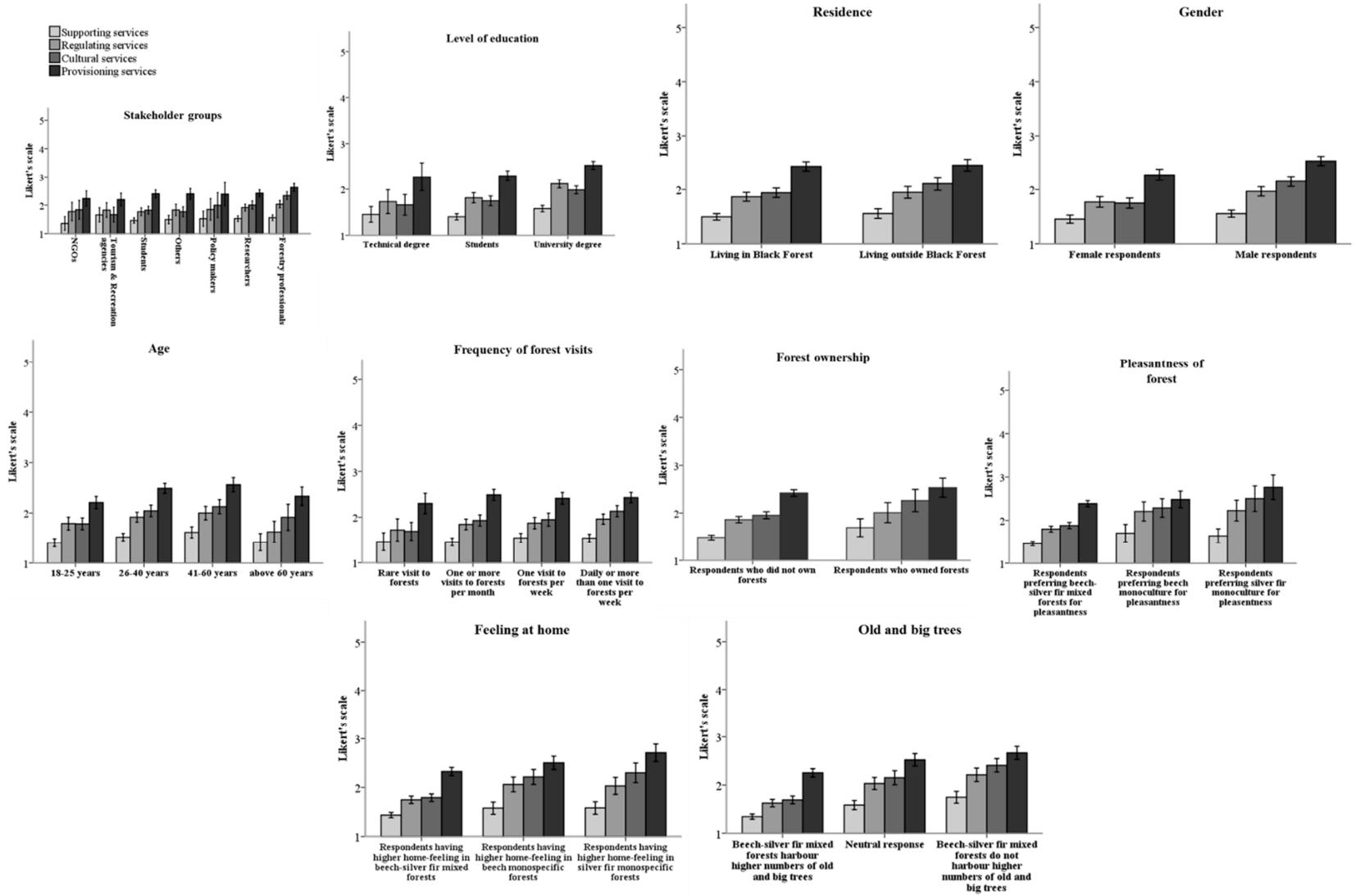

Figure 7. Variations of respondents' perceptions (i.e., average Likert scores) on supporting, regulating, cultural, and provisioning ecosystem services within 10 variables related to social profiles and preferences. The thin bars indicate the standard error of the average Likert score at a 95% level of confidence.

3.5. Influences of Social Profile and Preferences of the Respondents on Their Perceptions of Ecosystem Services

In the previous section, we showed how people's perceptions of ecosystem services varied within 10 variables related to their social profiles, habits, and preferences. We found four to six most important variables for each category of ecosystem services (Figure 8). Respondents' perceptions of the occurrence of big and old trees, the pleasantness of the forests, and their age and education were the four most important variables (Figure 8). Respondents' feelings of a higher number of old and big trees in mixed forests was significantly related to lower Likert values (i.e., better ecosystem services in mixed forests than monospecific forests) in all four types of ecosystem services (Figure 9). The perception of greater pleasantness of silver fir-beech mixed forests was also an important variable, and people with that perception were more likely to believe there are higher supporting, regulation and cultural services in mixed forests than in monospecific forests. The level of education was important; the beliefs about higher cultural, supporting, and regulating services in mixed forests over monospecific forests were significant among students and people with technical degrees. The age of the respondents was found to be an important variable for supporting, regulating and provisioning services. Young respondents (age 18–25 years) believed that mixed forests provide higher supporting ecosystem services; however, this trend was opposite for regulating and provisioning services. People who had a strong sense of feeling at home in mixed forests were more likely to believe that those forests provide higher cultural and provisioning services than monospecific forests. Gender was an important factor behind perceptions of the cultural ecosystem service, but not of other services. Male respondents were more likely than female respondents to believe that cultural ecosystem services were lower in mixed forests than monospecific forests. The stakeholder group (people were listed as per their profession) was found to be important only for cultural ecosystem services and not for the other services. People who were employed in the forestry sector were less likely to think that mixed forests provide higher cultural services than monospecific forests. Other professions were significant for the cultural services. The respondents who did not own any private forest lands were more likely to believe there are higher supporting ecosystem services in mixed forests than the private forest owners (Figure 9).

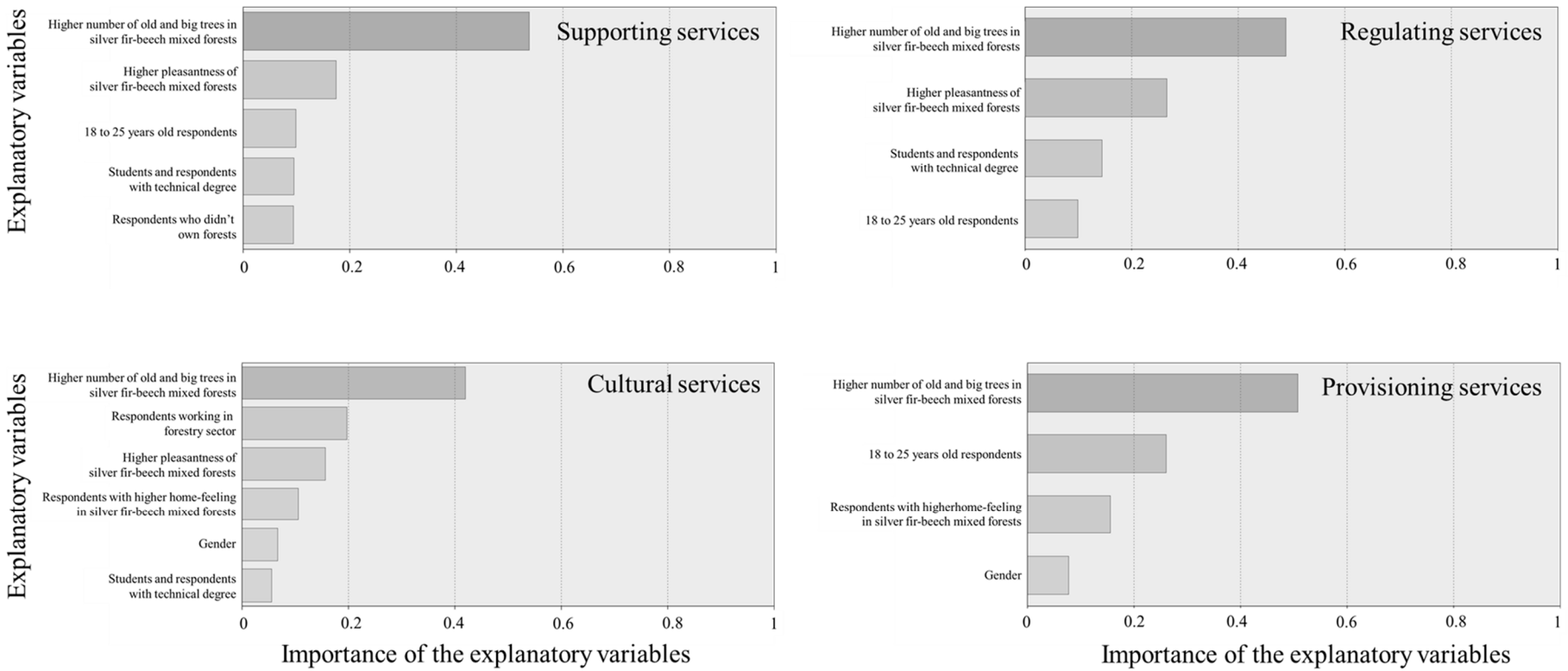

Figure 8. The most important explanatory variables included in final regression analyses based on their importance values generated during automatic stepwise regressions. Higher score denotes greater importance of a respective variable.

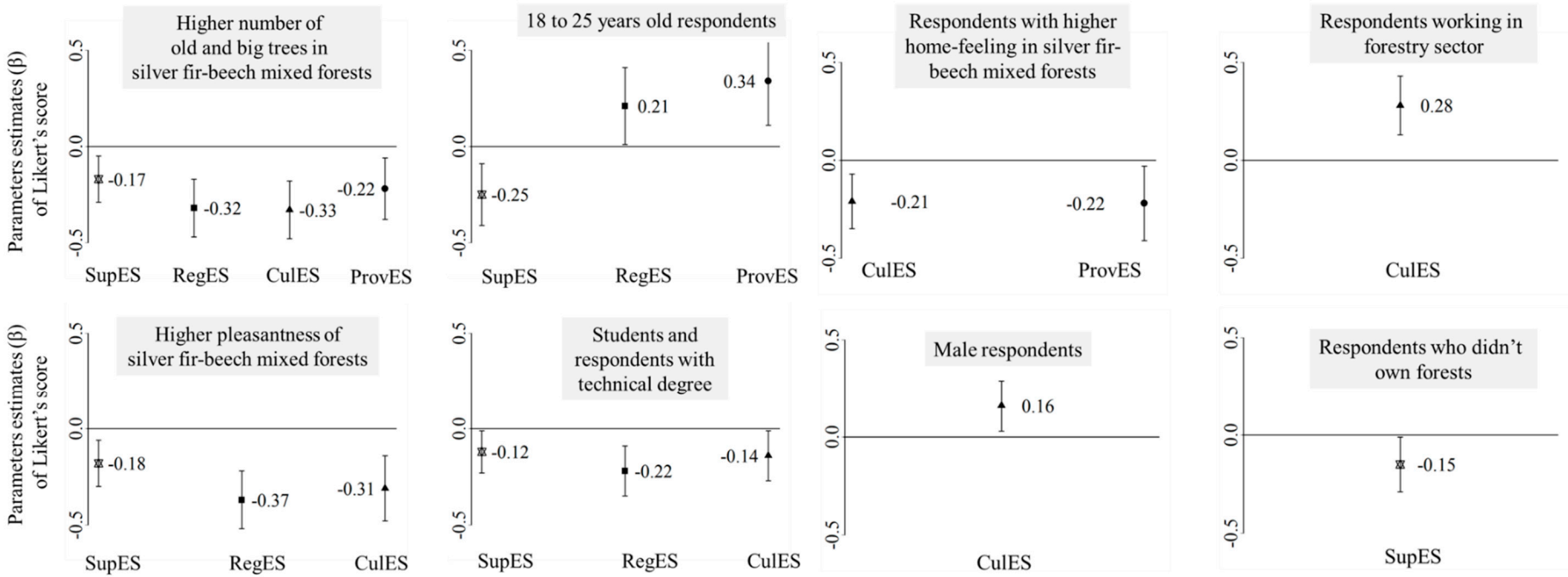

Figure 9. Results of four stepwise regression analyses for supporting (SupES), regulating (RegES), cultural (CulES), and provisioning (ProvES) services.

4. Discussion

In the present study, respondents' perceptions of ecosystem services provided by mixed and monospecific forests of silver fir and beech were assessed by the means of an online questionnaire. Respondents' level of agreement with 18 different statements about provisioning, cultural, regulating, and supporting ecosystem services were evaluated on a 5-point Likert Scale. The next step was to find out which important variables were having a significant effect on the respondents' perceptions about ecosystem services in mixed versus monospecific forests. The variables belonged to the social profiles of the respondents including age, gender, profession, and education level, among others. This was done by the means of stepwise regression models. The findings are discussed in the following three sections.

4.1. Respondents' Perceptions of Ecosystem Services Provided by Mixed Forests Compared to Monospecific Forests of Fir and Beech Trees

We found most respondents perceived that mixed forests provide better/preferred regulating, cultural, and supporting ecosystem services than monospecific forests of fir or beech. Supporting services received most positive perceptions, while provisioning services were perceived to be equally provided in mixed and monospecific stands, or even better in monospecific stands. These results are consistent with the results from past studies, as it was assumed that mixed forests ensure higher ecosystem functionality and show higher stability, resistance, and resilience against extreme events, such as drought and storms [4,13]. In addition, a higher diversity of tree species is promoted in forests as an adaptive measure to climate change impacts. However, a major discrepancy was found between respondents' perceptions and literature results on biomass productivity. While the literature indicates higher productivity in mixed species stands [53], respondents' perceived the productivity to be rather equal or worse in mixed compared to monospecific stands. A series of studies have exposed that a higher biodiversity in forests promotes the functionality of ecosystems, such as primary production, decomposition, nutrient cycling, and trophic interaction; thus ensuring a better provision of ecosystem services, including food production, climate regulation, and enhanced vitality, among others [7,19,20,54–56]. As a result, there is a growing trend for increasing the cover of mixed forests as a climate change adaptation strategy in Germany [57]. However, although there is general support for mixed forests by the public and scientific community, private forest owners and some forest economists still perceive that mixed forests are less profitable than monospecific stands of fast growing tree species. There have been many studies on the ecological benefits of mixed forests, especially in the context of climate change, yet sound economic assessments of mixed forests are still rare [58]. For instance, from a risk-aversion perspective, the economic value of mixed forests is believed to be greater, as a higher number of species is translated into higher resistance towards extreme events. In the case of beech and fir, an admixture of beech to monospecific fir stands is believed to increase stability and resilience [59]. Furthermore, it is known that mixed forests could deal better with the uncertainties of the future climate development than monospecific forests [60]. Nonetheless, this risk-aversion value is not always integrated in forestry financial models as such long-term economic benefits are not visible. As a result, many foresters might not yet be convinced of mixed forests being economically more profitable. In addition, many of them might be unwilling or hesitant to adopt modern approaches of mixed forest management. This might explain the neutral to negative respondents' perceptions on provisioning ecosystem services in mixed forests. Mechanization and management techniques are sometimes much simpler in monospecific forests than mixed forests. Therefore, foresters may believe that the costs of establishing, tending, and harvesting monospecific forests are cheaper than mixed forests. It has to be noted that supporting services, which obtained most of the positive levels of agreement, were also the ones obtaining the least D.K. ("I don't know") answers. On the other hand, provisioning services, which received the most neutral to negative responses, were the ones obtaining most D.K. answers. Our findings corroborate Carnol et al.'s [10] study, which obtained similar results in Belgium. In their study, supporting, regulating and cultural ecosystem services were

likewise perceived to be better in mixed species stands, while provisioning ecosystem services were perceived to be equal in mixed and monospecific stands.

Timber yield, profitability, hunting potential, and biomass productivity (all provisioning ecosystem services) are specific topics that require a certain degree of technical knowledge in order to be able to build an opinion. Hence, people who do not study forestry, nor have a forestry-related job, are less likely to be able to form their own opinion based on knowledge and/or experience. Conversely, cultural ecosystem services, such as tourism attractiveness and aesthetic value, are easily understood by people, regardless of their professional or academic background. There is no specific knowledge that is needed to form an opinion on many of the cultural services, as perceptions on these services can be based on people's own experiences and aesthetic preferences. Furthermore, people are directly dependent on cultural ecosystem services in their everyday life, such as recreational activities and tourism among many others [45]. Supporting ecosystem services, such as resistance to drought, diseases, and storms, together with resilience to climate change impacts, are topics that are addressed continuously in the policy agenda and in the media, as they play a crucial role in the climate change debate [61,62]. Furthermore, extreme events such as storms, floods, and droughts are already happening in Germany and other parts of world; as a result, climate change issues are increasingly being broadcast in mainstream German media [63–65]. Therefore, people might be more aware of the importance of supporting ecosystem services for climate change adaptation and mitigation, as well as for security and human well-being.

4.2. Respondents' Preferences between Mixed and Monospecific Forests of Fir and Beech

Besides perceived ecosystem services, another important variable in the present study was the respondents' preferences between mixed and monospecific forests of silver fir and beech. The aim was to find out first, whether the people surveyed preferred mixed over monospecific forests, and second, to test if those preferences influenced respondents' perceptions of ecosystem services.

The question of having a pleasant feeling was a subjective question, which aimed to elicit an opinion from the respondent based on both his/her emotional and rational processes of thinking or mind [66]. Whether a person receives a pleasant feeling from a certain forest landscape depends not only on visual values, such as scenic beauty and preferred forest features, which are based on emotions, but also on education, and practical or theoretical knowledge based on available information. For instance, preferences might have been based on information about the ecological advantages of mixed compared to monospecific forests in the context of climate change. This would account for more of a rational thought process. Two past studies on public preferences for different forest types revealed that mixed forests are generally preferred over monospecific forests [67,68]; which corroborates our results.

The response to the question about "feeling at home" (in German "Heimatgefühl") in a certain forest type was intriguing. The initial motivation for asking this question was to test whether people would feel more "at home" in coniferous forests, rather than mixed forests; as they might associate forests in the hilly region of southwest Germany with monospecific forests of two main conifer species: Silver fir and Norway spruce. Accordingly, it was expected that they would feel more at home in a silver fir forest rather than in a mixed fir-beech forest. Contrary to our expectations, it was found that most of the respondents felt more "at home" in mixed beech-fir forests. An explanation for this result might be that most of the survey respondents were holders of university or technical degrees and second, the majority of them were young persons aged between 18 to 40 years. Thus, they might be more aware/informed of the potential natural vegetation in southwest Germany, which would be mostly beech-dominated mixed forests with silver fir and other species.

4.3. Influence of Multiple Factors on Respondents' Perceptions

Overall, respondents' perceptions of all four types of ecosystem services were influenced by their feeling that mixed forests harbor higher numbers of old and big trees. Edwards et al. [67] undertook

a survey using the Delphi technique in Great Britain, the Nordic Region, Central Europe, and the Iberian Peninsula, and found that the "size of trees within stand" was the most important variable influencing peoples' preferences for the potential forest types. Gundersen and Frivold [66] reviewed 53 studies (published from 1972 to 2004) on forest landscape preferences in Fennoscandia. They found that people prefer forests with an irregular structure constituting of smaller as well as big trees, due to higher recreation values, in contrast to regular even aged forests. In addition, Ribe [68] listed 14 studies (published from 1967 to 1986) which showed tree size was an important factor for people's preferences to visit urban parks, national parks, and other recreational forests. Old and big trees sustain a wider range of ecosystem functions and services, such as carbon storage, soil development, water storage, wood volume, and provision of habitat; thus allowing for the occurrence of higher species diversity. For instance, arboreal wildlife species prefer large trees as a habitat, and several wood-living species are restricted to large dimensions. Likewise, many threatened species among the insects and fungi only develop in large trees [69]. Hence, maintaining some old trees in forest stands can be a crucial strategy for maintaining biodiversity during impacts caused by climate change [70]. This may explain the link between respondents' perceptions of the abundance of old trees in mixed forests and the provision of preferred ecosystem services. Respondents who perceive that old trees are usually more likely to be found in mixed forests, and at the same time, are aware of the ecological advantages of maintaining old growth in forests, will consequently perceive that mixed forests provide better ecosystem services than monospecific forests. People's perceptions of the occurrence of big trees may also be related to the silvicultural systems that are associated with the management of mixed and monospecific forest stands. Monospecific forests are generally managed by a clear-felling system, which requires the creation of wide gaps to promote natural regeneration and the systematic removal of big trees after a certain diameter has been reached. In contrast, mixed forests stands were generally managed under the principles of close to nature silviculture or *Dauerwald* systems, where a certain proportion of big trees are kept aside as habitat trees [71].

Respondents who experienced a greater feeling of pleasantness in mixed forests were more likely to perceive that supporting, regulating, and cultural ecosystem services are better provided in mixed forests. The positive relationships between perceptions of cultural services and the pleasantness of mixed forests can be explained by the fact that public preferences of natural landscapes (in this case, forest landscapes), are usually based on perceptions of "aesthetic beauty" [67,68]. Brown and Daniel [72] reported that visual attractiveness increases the pleasantness of forests to visitors and influences the recreational value of a forest. Nevertheless, these perceptions can vary depending on the social profiles of respondents. Traditionally, scenic beauty was considered to be a by-product of well-managed park-like forests near to human habitation in Europe. However, public concerns about aesthetic beauty in natural environments or wilderness areas gained more importance; thus, innovative techniques to measure the "aesthetic value of natural landscapes" started to emerge. Since 1970, there have been many empirical assessments about public preferences of natural landscape scenery, particularly of forests [68]. In addition, according to Ribe [68], scenic beauty was not only considered an important "forest product", but perceptions of the beauty of forests were important measures for forest management decision-making. Yarrow [73] for instance, found that many British respondents were willing to compromise timber yield values to a certain degree to increase the beauty of the forests. When assessing public preferences between managed and unmanaged forests among French respondents, he found that choice was influenced by social groups, age, and profession. For example, he reported that young men, people living in rural areas, industrial workers, and farmers preferred managed forests, while young women and more educated Parisians preferred unmanaged forests. In our study, we also found that male respondents were less likely to believe that mixed forests provide better cultural services than monospecific forests. Similarly, Martín-López et al. [47] found a different awareness of environmental services between males and females, stating that females were more likely to perceive the capacity of forests to provide ecosystem services. In particular, female respondents were more likely to perceive regulating services, while male respondents were

more likely to perceive provisioning services. However, involvement of females in the forestry sector is generally lower than their male counterparts. Therefore, gender perceptions should be interpreted cautiously. Nevertheless, our findings support the result from Carnol et al. [10], who found that the socio-economic and gender contexts, together with a rural versus a highly urbanized residential situation, can explain the differences in stakeholders´ perceptions. The finding that perceptions of regulating and supporting services were positively related to greater pleasantness of mixed forests suggests that the answers of respondents were not only based on preferences of "visual beauty", but also on information and knowledge. More precisely, respondents might have been informed about the ecological advantages of mixed forests in the context of climate change, as discussions on this topic are ongoing. Carnol et al. [10] found similarly, that local or scientific knowledge has an influence on stakeholders' perceptions of the provision of ecosystem services in mixed forests.

Surprisingly, a higher "feeling at home" in mixed forests had an influence on respondents' perception of a better provision of not only cultural, but also provisioning services in mixed forests. This interesting finding reinforces our explanation that most of the respondents are aware of the natural potential vegetation in Southwest Germany and are informed of the multiple advantages of mixed forests over monospecific forests.

Similarly to the findings by Yarrow [73], Plieninger et al. [46], Martín-López [47] and Carnol et al. [10], we found that socio-demographic profiles in our study, particularly age and education level, are also important explanatory variables influencing respondents' perceptions of ecosystem services. As such, respondents between 18 and 25 years old were more likely to perceive a higher provision of supporting ecosystem services in mixed forests, suggesting a possibly higher awareness of younger respondents about the greater resilience of mixed forests in the context of climate change.

In contrast to the findings by Martín-López et al. [47], which have shown that people with a higher formal education level are more likely to perceive a better provision of ecosystem services in mixed forests, our results show that students and people with technical degrees were more likely to perceive better supporting, regulating, and cultural services in mixed forests, compared to people holding a university degree. However, it is worth mentioning that unlike Martín-López et al. [47], all of our respondents had obtained a certain level of formal education. This result suggests that a higher formal education is not necessarily associated with the perception of a better provision of ecosystem services in mixed forests. In Section 4.1, we suggest that the comparatively negative perceptions of provisioning ecosystem services in mixed forests are due to respondents being employed in the forestry sector. However, the regression analyses showed significant results only for cultural services, as this stakeholder group was less likely to perceive a higher provision of cultural services in mixed forests. A lower perception of management costs in monospecific forests than in mixed forests in this stakeholder group could also be a reason for this result, as discussed above. More research, including personal interviews, are needed to be able to draw reliable conclusions on this finding.

The results of our online survey reflect the perceptions of well-educated persons between the ages of 26 to 60. The meaningfulness of our findings for younger and older people are limited because of their lower representation in the survey. The participation of older people (age > 60 years) was only 7%. The latest German census records that 40.5% of the population is over 60 years of age [74]. Therefore, the perceptions of ecosystem services in this age group were significantly underrepresented in our study. The reason was probably that older people are less involved in using internet than younger people. With a classical technique such as a postal survey, more older people could have been reached, but vice versa fewer younger people.

Another limitation of the study was how to adequately explain to the respondents what was meant by mixed and monospecific forests. We defined monospecific forests and mixed forests, presented photographs of mixed and monospecific forests of silver fir and beech, and provided descriptions of the species in the introduction to the questionnaire to minimize the bias.

5. Conclusions

In the present study, the perceived ecosystem services provided by mixed compared to monospecific forests of silver fir and European beech forests were assessed by the means of an online questionnaire. The findings stated that overall there is a general awareness of mixed forests providing better ecosystem services than monospecific forests of fir and beech. In addition, mixed forests are generally preferred over monospecific forests. It was also found that supporting, regulating, and cultural services were perceived to be better in mixed rather than monospecific forests, while provisioning services were perceived as being equal or better provided in monospecific forests of fir and beech. The contrasting perceptions on provisioning services highlighted the need for better communication and information flow on profitability, biomass, and timber productivity in mixed forests. Lastly, the study demonstrated that social profiles and preferences have a significant influence on perceived ecosystem services. It was found that respondents who perceived a higher abundance of old and big trees in mixed forests were more likely to fully agree on a higher provision of ecosystem services in mixed forests. The same effect was caused by feeling more pleasant in mixed forests. One of the major contributions of this study is that this has been the first study in Germany to assess people's perceptions on ecosystem services in mixed and monospecific forests. Additionally, this study assessed cultural ecosystem services, which have been rarely assessed in the literature, except for economic assessments of tourism and recreation. Finally, it contributes to filling the gap between formal scientific knowledge and people's perceptions of the provision of forest ecosystem services. Conclusively, the study shows the paramount importance of further research in this field, as it provides an understanding of people's perceptions and motivations with regards to their environment. These perceptions, if better understood by policy makers, will lead to effective and efficient policies of forest management being implemented, which will in turn provide more viable ways to mitigate and adapt to climate change in the long run. This study using an online questionnaire survey will help to conduct a more detailed study on stakeholders' perceptions of mixed and monospecific forests using structured communication techniques such as the Delphi method.

This study contributes to the achievement of Sustainable Development Goals 13 "Climate Action", and 15 "Life on Land", as it analyses public attitudes and perceptions of mixed forests and enhances public awareness about the importance of ecosystem services they provide. Furthermore, it improves knowledge about the resilience and adaptive capacity of forests in Southwest Germany towards negative impacts caused by climate change. In addition, it serves as an instrument to contribute to Goal 15.9, which aims to integrate ecosystem and biodiversity values into national and local planning [9].

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