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Does gender really matter? How demographics and site characteristics influence behavior and attitudes of German small-scale private forest owners

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ABSTRACT

When analyzing management behaviors of small-scale private forest owners, demographic variables such as income, age, or profession, and land characteristics such as forest holding size often emerge as important drivers. However, gender is frequently used in targeted outreach, even though the other variables regularly show higher predictive power. To shed light on this discussion, we examined the influences of a broad set of predictors including both land characteristics and sociodemographic factors such as gender on management activities, owner goals, perceived obstacles, and conservation attitudes as response variables. We used a questionnaire survey to collect quantitative data from 1268 small-scale private forest owners in northwestern Germany. Random forest models were used to predict the responses and to rank the predictors according to their variable importance. We found that the size of forest holdings often had a strong influence on economic activities, while the amount of broadleaf forest was important for conservation-oriented management decisions. While gender-specific outreach is a strong tool to empower formerly marginalized forest owner groups, gender was not found to be an important predictor of forest management activities in our analyses. We advocate considering other characteristics when conceiving communication with forest owners. In order to design carefully targeted policy instruments and outreach to forest owners, we propose a set of easily accessible owner parameters and land characteristics. These factors can guide more individualized conservation outreach strategies in small-scale private forests that are embedded in the overall livelihood systems of their owners.

1. Introduction

Today's forests face a variety of crises (Pörtner et al., 2023). The climate crisis is affecting forests in many ways, causing global changes such as increased likelihoods of wildfires, more insect pests, and longer periods of drought (El Garroussi et al., 2024; Hlásny et al., 2021; Markonis et al., 2021). The biodiversity crisis, fueled by a continuous loss of old-growth forest structures (Potapov et al., 2017), affects rare and specialized forest species (Betts et al., 2017). As large pools of carbon sequestration and biological diversity, forests are needed in solving global crises, and their resilience will continue to depend on the conservation of their biodiversity (Ibarra et al., 2020). At the same time, society's demands on forest ecosystems are becoming increasingly complex (Winkel et al., 2022). In large parts of Europe and the USA, much of the forest is owned by private organizations and individuals (United Nations Economic Commission for Europe, 2020). This is also the case in Germany, where 43.0 % of the total forest area is privately owned, and 18.4 % of the total forest area is divided into small-scale private forest (SPF) of less than 20 ha (Statistisches Bundesamt, 2023a, Statistisches Bundesamt, 2023b). The group of SPF owners is large and diverse, with widely varying attitudes and management strategies (Tiebel et al., 2024; Weiss et al., 2019b). While private forest owner associations often convey a relatively uniform view of their members as primarily pursuing economic goals, other goals such as recreation or nature conservation have become increasingly important to SPF owners in recent times (Weiss et al., 2019b; Weiss et al., 2019a).

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SPFs in Germany often comprise a diverse mosaic of tree species, age classes, structures, and different management approaches, often leading to high structural and habitat diversity on the landscape scale (Hansen et al., 2023; Johann and Schaich, 2016). However, the lack of institutional organization among many SPF owners can also be an obstacle when it comes to offering advice and help or promoting new policy tools (Joa and Schraml, 2020).

Against this background, research has sought to identify factors that are major predictors of SPF owners' goals and ultimately management decisions. It was found that sociodemographic factors are particularly important variables influencing SPF behavior. As prominent characteristics of SPF owners such as gender distribution, age, or urbanity are changing (Butler et al., 2016; Eggers et al., 2014; Sass et al., 2023), impacts on SPF management activities can be expected (Nordlund and Westin, 2011). Understanding the factors that influence the attitudes and behavior of SPF owners is essential for designing targeted outreach strategies to engage them in promoting mitigation and adaptation to a changing environment to ensure the provision of vital ecosystem services. Current research has focused on individual single factors, such as gender, ethnicity (Robillard et al., 2023), geographic distance (Caputo and Snyder, 2023), or forest parcel size (Butler et al., 2021), and provided in-depth analyses of their relationship to target variables, such as forest owner behavior.

A large body of research has attempted to characterize owners according to whether they identify as female or male. It was established that female forest owners have more positive attitudes toward nature conservation (Kuhlman et al., 2022; Tiebel et al., 2022; Umaerus et al., 2019), and that they identify more with aesthetic perspectives regarding their property (Tiebel et al., 2022). They cut less timber (Lidestav, 1998; Lidestav and Ekström, 2000) than their male counterparts, while being more price-sensitive (Follo et al., 2017) and wanting to maintain their property in the best possible way (Krause and Enzensbach, 2008; Redmore and Tynon, 2011). On the other hand, it has been suggested that female owners value timber production as much as male owners (Böhling, 2022), but that they are additionally interested in recreational and social values, and are open to alternative business ideas such as tourism (Umaerus et al., 2019). Careful forest management is seen as a high priority for female forest owners (Schlecht and Westermeyer, 2010), and while being more likely to admit a personal lack of information, they might seek support more likely than male owners (Andersson and Lidestav, 2016; Hamunen et al., 2020; Schlecht and Westermeyer, 2010). Female forest owners express a greater need for assistance and learning opportunities, and more concern about invasive species (Berget and Dwivedi, 2024). In addition to economic activities, active forest ownership for female owners involves taking care of forests and their species (Kuhlman et al., 2024). Gender-specific outreach for women is presented as a way to increase their engagement in an environment that is described as male-dominated and intimidating (Carter, 2019; Lukacic et al., 2023; Miner et al., 2021).

However, it can be asked whether a strong focus on a single characteristic of forest owners is sufficient when trying to efficiently identify owner groups for targeted outreach and policy instruments. This question has been raised, for example, by Butler et al. (2017) in relation to gender as a potential driver of differences in forest management activities. Research has taken on a multifactorial approach to identify factors that influence SPF owners' management activities such as timber harvesting, which is considered one of the most important activities performed in forests (Table 1). In a seminal work by Binkley (1981), the probability of timber harvesting was influenced by multiple sociodemographic factors like profession and income of the owner, but also by site characteristics (forest parcel size) and market drivers (timber prices). Through a review of the literature, Beach et al. (2005) analyzed timber harvesting patterns and related silvicultural activities like reforestation. They found that logging activity depends on parcel size, stock quality, and market prices, while activities such as reforestation are strongly linked to policy instruments like government cost sharing. In addition, silvicultural treatments, such as timber stand improvement and young growth tending, depend on parcel size, but also on sociodemographic factors like income, age, education, and urbanity of the owners (Beach et al., 2005). In a study by Kuuluvainen et al. (2014), the harvesting behavior of Finnish SPF owners was mainly influenced by stock quality, parcel size, and the age and occupation of the owner. Silver et al. (2015) identified market prices, the existence of a management plan, education, timber stock quality, and parcel size as drivers of timber harvesting. Size, urbanity, the existence of a management plan, gender, and length of tenure were important predictors of timber harvesting in Côté et al. (2016).

Other authors focused on more complex behavioral variables, such as different management strategies that SPF owners use on their property. Eggers et al. (2014) looked at predictors of five different management strategies, and again parcel size was identified as an important predictor. Among owner demographic variables, forestry profession played a small role, but other variables such as gender and urbanity did not show a strong correlation with the management strategies. A different set of management strategies was studied by Juutinen et al. (2020), who contrasted traditional strategies with more modern approaches such as uneven-aged management. The forest owner's profession, urbanity, education, age, and gender had strong influences on the choice of strategy. Husa and Kosenius (2021) investigated the willingness of forest owners to adopt different management practices that affect timber production, biodiversity, carbon sequestration, and adaptation to climate change. Important predictors of response variables include age, education level, and income of forest owners, as well as parcel size. A broader set of activities related to harvesting, silviculture, property management, and care for wildlife and recreation was examined by Joshi and Arano (2009). Here, forest owner age, education, profession, and income were identified as predictors of harvesting and related silvicultural practices, while property management for wildlife and

Table 1
Multifactorial work on the influences of demographics, site characteristics, market drivers, and policy instruments on different activities of forest owners. The key predictors are listed.

Work	Response variable	Important predictors
Binkley (1981)	Timber harvesting	Parcel size, timber price, profession, income
Beach et al. (2005)	Timber harvesting	Parcel size, stock quality, timber price
Joshi and Arano (2009)	Timber harvesting	Profession, education, income, age
Kuuluvainen et al. (2014)	Timber harvesting	Parcel size, stock quality, profession, age
Silver et al. (2015)	Timber harvesting	Parcel size, stock quality, timber price, management plan, education
Côté et al. (2016)	Timber harvesting	Parcel size, length of tenure, management plan, gender, urbanity
Beach et al. (2005)	Reforestation	Policy instruments
Beach et al. (2005)	Silvicultural treatments	Parcel size, education, income, age, urbanity
Eggers et al. (2014)	Management strategies	Parcel size, profession
Juutinen et al. (2020)	Management strategies	Profession, gender, education, age, urbanity
Floress et al. (2019)	Management behavior	Parcel size, knowledge, past behavior, attitude
Husa and Kosenius (2021)	Willingness to apply activities	Parcel size, education, income, age
Joshi and Arano (2009)	Managing for wildlife	Type of acquisition, income, age, urbanity

recreation depended on the type of acquisition and owner's income, age, and urbanity. In a literature review of factors influencing 13 different categories of behavior related to forest management, Floress et al. (2019) described a variety of influences from factors such as parcel size, knowledge, and past behavior. Owners' attitudes, such as their concern for the environment, were identified as good candidate predictors, while owners' goals showed poor correlation with their actual behavior. In summary, existing multifactorial research on the determinants of SPF owner activity has identified a number of relevant variables, including sociodemographic traits, site characteristics, market drivers, and management goals.

The focus of this study is to identify predictors not only of SPF owners' behavior, but also of their management goals, perceived obstacles to their goals, and attitudes toward conservation. As predictors, we use sociodemographic variables, such as gender, age, and urbanity, and site characteristics like forest parcel size, stand age, and proportion of broadleaf trees. By combining a broad set of predictors in multivariate models, the relative importance of each variable will be assessed, attempting to answer the question of which individual factors (e.g., gender) are actually driving the response variables. For organizations designing policy or outreach instruments for SPF owners, it will be convenient that our variables are either already available or relatively easy to collect from the target group. We aim to answer the following research questions:

- How can the management activities of SPF owners be predicted from easily accessible sociodemographic data and forest parcel characteristics?
- Can this approach be extended to the owners' goals, perceived obstacles, and conservation attitudes?
- What are the most important predictors of the activities, goals, obstacles, and conservation attitudes of SPF owners?

Based on these results, we will discuss the implications for owner outreach and the conservation promotion in small-scale private forests.

2. Methods

2.1. Quantitative survey

The present analysis uses quantitative data collected through a postal and online questionnaire sent to all 4202 private forest owners in parts of Lower Saxony (Germany) in 2020 (Tiebel et al., 2024; Tiebel et al., 2021) who are organized in three local forest owners' associations. The Lower Saxon Hills region was chosen as the study area because of its consistent legal situation and uniform forest administration. 43 % of the forest in the study area is privately owned, of which 91 % consists of parcels smaller than 20 ha; this is comparable to many Western and Central European countries (ML, 2014). The survey followed Dillman's Tailored Design Method (Dillman et al., 2014) and consisted of 26 questions related to sociodemographic parameters, site characteristics, owner attitudes, and framework conditions (Tiebel et al., 2021). Of the 1671 original responses (response rate 39.8 %), only those SPF owners with a total property area of at most 20 ha were selected for the present study, resulting in a dataset of size $n = 1268$. The upper threshold of 20 ha was chosen to meet the definition of small-scale private forest in Germany (ML, 2014). It is possible that there is some non-response bias in the result set. Individuals with less interest in the topics of the questionnaire may have been less likely to participate in the study, while people with more interest or free time may have been over-represented. This needs to be taken into account when generalizing the results. The representativeness of the dataset used in our study was examined in detail in Tiebel et al. (2021), where we conclude that the assessed ownership and forest structures are comparable to German-wide data (Feil et al., 2019) and European surveys (Schmithüsen and Hirsch, 2010). In terms of sociodemographic factors, our participants show a similar gender and age distribution, but a more rural orientation than private forest owners in Germany as a whole, while being comparable at the European level.

2.2. Predictors and response variables

From the questionnaire, we selected a set of 13 variables related to forest parcel characteristics and owner demographics that are commonly understood to potentially influence owner goals, attitudes, and behaviors (Table 2). The granularity of the variables differed in the questionnaire, e.g., the proportion of broadleaf forest was sampled using four classes (below 25 %; 25–50 %; 50–75 %; above 75 %), while there were three possible responses to the question on forest age (below 40 years; 40–100 years; above 100 years). During preliminary model runs, it was observed that predictors with finer granularity were over-selected by the models (see also Section 4.4). To eliminate this effect and to facilitate comparisons between driving variables, the data for each predictor were dichotomized into two classes, sacrificing some of the information originally present in the data and turning the predictors into binary variables (see Sass et al. (2023) for a similar approach). The aggregation was performed so that the sizes of the two resulting classes per variable were as equal as possible to allow the regression or classification algorithm to extract as much information as possible from a binary predictor. It was verified that this aggregation step had negligible influence on the predictive power of the models.

We analyzed the influence of the driving variables on the response variable groups management activities, owners' goals, perceived obstacles, and attitudes toward conservation (see Table 3 and Appendix Table A1). Goals and attitudes were queried using a 5-point Likert scale (1 = strongly disagree; 2 = rather disagree; 3 = neutral; 4 = rather agree; 5 = strongly agree), while questions for activities and obstacles could be answered yes or no.

Missing values in our dataset (i.e., the respondent did not select an answer to the question at all) were replaced by modeled values using

Table 2
Predictors as assessed in the questionnaire and coded as either 0 or 1, after 3NN imputation.

Predictor	Description	Mean
Broadleaf	Equals 1 if the amount of broadleaf forest property is larger than 50 %, 0 otherwise	0.620
Forest age	Equals 1 if the average stand age is over 40 years, 0 otherwise	0.746
Total size	Equals 1 if the total forest property size is over 2.5 ha, 0 otherwise	0.501
Number of parcels	Equals 1 if owner owns more than one forest parcel, 0 otherwise	0.567
Bought or leased	Equals 1 if the forest land is bought or leased (as opposed to inherited, gifted, etc.), 0 otherwise	0.272
Distance	Equals 1 if the owner lives more than 10 km away from their forest, 0 otherwise	0.188
Formal training forestry	Equals 1 if the owner has a formal (professional or university level) training in forestry, 0 otherwise	0.068
Female	Equals 1 if the owner identifies with female gender, 0 otherwise	0.194
Owner age	Equals 1 if the owner is older than 65 years, 0 otherwise	0.353
Professional qualification	Equals 1 if the owner has completed a professional training program (as opposed to only having finished secondary school), 0 otherwise	0.710
Agriculture/forestry	Equals 1 if the owner is a professional in agriculture or forestry, 0 otherwise	0.306
Time in forest	Equals 1 if the owner spends time in their forest during job or leisure, 0 otherwise	0.692
Settlement size	Equals 1 if the owner has spent most of their time in a settlement of over 5000 inhabitants, 0 otherwise	0.306

Table 3
Response variables (management activities, owner goals, perceived obstacles, and attitudes toward conservation). For details, see Table A1 in the Appendix.

Response variable group	Response variables	Coding
Management activities (carried out)	Pruning; thinning; protection of young plants against deer browsing; timber sale; planting/promotion of native tree species; planting/promotion of introduced tree species; protection of habitat trees; reduction of damage due to logging; avoidance of chemical pesticides; coppicing/coppicing with standards; wood pasture; promotion of a shrub layer; promotion of broadleaf trees in coniferous forests; protection/restoration of light stand structures; protection/ maintenance of special structures; use of logging horses; promotion of rare native tree and shrub species; promotion of natural tree regeneration; avoiding clearcuts; protection of dead wood; harvest of single mature trees; species protection measures; biotope restoration; removal of introduced species; non-use of parts of the stand; none	0 or 1
Owner goals (importance of)	Wood production for selling; wood production for personal consumption; collection of non-wood products; possibility for own recreation; possibility for hunting; protection as a cultural asset; safeguarding or enhancement of landscape beauty; preservation as a place of education; possibility for nature observation; long-term preservation of a stable and healthy forest stand; carbon sequestration, conservation of carbon sinks; biodiversity conservation; protection of soil, water, air quality; preservation for financial security; profit maximization; preservation of family heritage	5-point Likert
Obstacles (perceived)	Lack of time; lack of money; lack of technical equipment; lack of skills; lack of knowledge; lack of information; lack of family labor force; forest size is too small; unclear boundaries of the forest; unknown contact persons; poor accessibility through forest roads; uncertainty about the location of the forest; distance between forest and living place; too much effort; lack of interest; initial stand conditions unfavorable for my objectives; no notable restrictions	0 or 1
Attitudes concerning nature conservation (agreement with)	Structures with high conservation value are present in my forest; my management ensures natural forest conditions; even without financial support, I am willing to promote nature conservation; my forest provides no other benefit to me, which is why I promote nature conservation; nature conservation in my forest continues the family tradition; nature conservation in my forest implies refraining from any use; extraction of renewable resources is more meaningful than nature conservation; conservation in my forest can limit recreational uses; conservation in my forest prevents a visually beautiful impression; conservation in my forest threatens my personal freedom of decision; conservation in my forest creates high costs; I do not perform management due to difficult forest stand conditions; I would like to see higher involvement in decision making processes about conservation; I perceive the management restrictions as too strict	5-point Likert

3NN imputation (Templ et al., 2022). Nulls were relatively rare in the data, with the following average percentages per category: predictors (2.4 %), management activities (0.0 %), goals (4.7 %), perceived obstacles (2.2 %), attitudes toward conservation (14.7 %).

2.3. Bivariate statistics

To assess linear correlations between each predictor and each response variable, we calculated bivariate correlations using Kendall's τ. In addition to their absolute value, these measures indicate the direction of influence (positive or negative) of a predictor on a response variable.

2.4. Multivariate analyses: Random forest classification and regression

For each response variable, we built a random forest model (number of trees: 501) that included all the predictors. Models were trained and evaluated using 5-fold cross-validation (Kuhn, 2023). We used two different quality criteria to assess the predictive power of the overall final model, depending on the response variables: Regression models for Likert-scale response variables (goals and conservation attitudes) were assessed by their R^2 value. For binary response variables (management activities and perceived obstacles), the classification models were assessed using Cohen's kappa (κ). While R^2 values and κ values both provide information on the predictive power of models, i.e. the amount of variance that they explain, some care is needed when interpreting such values. Relatively low numerical R^2 values such as 0.090 might already express a medium effect size (Cohen, 1988), while a κ value of 0.200 is needed to speak of fair agreement strengths (Landis and Koch, 1977). Some authors set the bar even higher (Shrout, 1998).

Regarding the importance of individual predictors in a model, random forest models provide a natural ranking of these variables (Archer and Kimes, 2008), where the most important predictor is assigned a value of 100 %, and the others are subsequently assigned smaller percentage values according to their importance in building the decision trees of the model. For visualization purposes, we weighted the importance of the driving variables by the predictive power of the model (R^2 or κ values), e.g., a predictor with 80 % importance in a model with a κ value of 0.080 would appear with an importance measure of 6.4 in our final results. All analyses were performed using R 4.4.1 (R Core Team, 2020). Multicollinearity testing of the predictors was done by calculating variance inflation factors, which were below 1.3 for all tested variables.

2.5. Presentation of results

We examined the random forest models for each variable in the four response variable groups and ranked the models by their predictive power (Fig. 1), starting with the model with the highest predictive power in each group. We report the R^2 or Cohen's kappa (κ) value of the model and its most important predictors. Variable importance (*vi*) values are given as integers, with 100 used for the single most important variable, and subsequently less important variables receiving smaller values. For visual comparability, the *vi* values in Fig. 1 were weighted by the predictive power of the model and given a sign according to the direction of the bivariate correlation of the individual predictor and the response variable. When an important predictor was identified, the distribution of that variable in the population of SPF owners in our sample is described in the results section (see also Table A2 in the Appendix). For binary responses (activities, obstacles), the percentage of "yes" responses is given. For Likert responses (goals, attitudes), Likert scores "rather important (4)" and "very important (5)" were combined, and the percentage of those responses is given.

3. Results

3.1. Management activities

Variables related to different management activities (Fig. 1a) were given as binary yes/no answers in the questionnaire. We used Cohen's kappa (κ) values as a measure of the predictive power of the models. The predictive power of the management activity models was often relatively strong, with an average κ value of 0.075, and eleven of the 26 models having κ values above 0.050. These are presented in the following, along with their strongest predictors.

The response variable scoring highest was *timber sale* ($\kappa = 0.340$), which the random forest model was very successful in predicting from our driving variables. It was most influenced by *total size* ($vi = 100$) and *broadleaf* ($vi = 71$). Owners of more than 2.5 ha of forest land sold timber

Fig. 1. Weighted variable importance of the 13 predictors in random forest models for (a) management activities, (b) owner goals, (c) perceived obstacles, and (d) conservation attitudes. Negative sign if the bivariate correlation coefficient is negative. Weighting is done by multiplying the variable importance given by the random forest model by the model's predictive power [Cohen's kappa for (a), (c); R^2 for (b), (d)]. Models with predictive powers lower than 0.01 are not shown. The bubble diameter is proportional to the absolute value of the weighted variable importance.

in 75.6 % of the cases, while only 46.6 % of owners of smaller parcels sold timber. Ownership of forests with predominantly broadleaf trees reduced timber sales, with 52.7 % of their owners selling compared to 74.9 % of owners of predominantly coniferous forests. *Habitat-tree protection* ($\kappa = 0.236$) was influenced with almost equal strength by the variables *broadleaf* ($vi = 100$) and *bought/leased* ($vi = 97$). Owners of broadleaf-dominated forests were inclined to protect habitat trees in 50.6 % of the cases, while only 32.8 % of owners of conifer-dominated stands did so. Owners who bought or leased their land were more likely to protect habitat trees (58.3 %), while 38.5 % of the owners who passively came into possession of their forest chose to protect. The model for *reduce logging damage* ($\kappa = 0.226$) showed a single strong influence by *total size* ($vi = 100$). 63.3 % of owners of parcels larger than 2.5 ha try to reduce damage from logging, while the percentage for owners of smaller parcels is 39.8 %. *Harvest of single mature trees* ($\kappa = 0.226$) was influenced by the predictors *agriculture/forestry* ($vi = 100$) and *forest age* ($vi = 62$). The activity was more frequently chosen by agricultural or forestry professionals (64.9 %), with only 39.9 % of the other owners choosing this strategy. The model for *promotion of natural tree regeneration* ($\kappa = 0.210$) was influenced by the predictor *total size* ($vi = 100$), but almost equally strongly by *time in forest* ($vi = 90$). Owners of parcels larger than 2.5 ha were more likely (66.6 %) to rely on natural regeneration, compared to 45.8 % of owners of smaller parcels. This strategy was also chosen by 62.6 % of people who spend time in forests, compared to 41.8 % of people who do not visit forests during job or leisure. A similar situation was found for the model of *protection of young plants against deer browsing* ($\kappa = 0.200$), with *total size* ($vi = 100$) and *time in forest* ($vi = 80$) as the most important predictors. Larger-scale owners protected against browsing in 55.3 % of the cases, compared to 35.7 % of the other owners. Of those people who spend time in forests, 51.1 % protected against browsing compared to 32.8 % of others. The activity of *planting/promotion of introduced tree species* ($\kappa = 0.125$) was influenced almost equally by the predictors *broadleaf* ($vi = 100$) and *total size* ($vi = 98$). Owners of predominantly broadleaf forests preferred not to plant foreign species (only 21.6 % did so), while 41.1 % of the other owners performed this activity. On the other hand, parcel size had a positive influence, with 39.7 % of owners of larger parcels planting introduced species, compared to only 18.3 % of owners of smaller parcels. *Planting/promotion of native tree species* ($\kappa = 0.116$) depended on *total size* ($vi = 100$), but also on *time in forest* ($vi = 67$). While 73.2 % of the larger-scale owners planted native species, 55.8 % of the others did so. Spending time in forests also increased the likelihood of planting native species, with 69.2 % of forest-visiting owners doing so, compared with 53.8 % of the others. *Protection of dead wood* ($\kappa = 0.110$) was mostly dependent on *broadleaf* ($vi = 100$). 50.9 % of the owners of predominantly broadleaf forests managed for deadwood, while only 35.1 % of the other owners did so. A similar situation was found for the activity of *avoiding clearcuts* ($\kappa = 0.096$), which also depended mostly on *broadleaf* ($vi = 100$). Owners of broadleaf forest avoided clearcutting in 73.4 % of the cases, while 53.1 % of the other owners avoided it. The activity *promotion of broadleaf trees in coniferous forests* ($\kappa = 0.090$) was negatively influenced by *broadleaf* ($vi = 100$), but promoted by *total size* ($vi = 87$). Owners of predominantly broadleaf forests reported this activity in 39.1 % of the cases, compared to 50.8 % of the owners of predominantly coniferous forests. Owners of parcels larger than 2.5 ha promoted broadleaf trees in 49.3 % of the cases, compared to 37.8 % of the other owners. Models for the remaining activities had predictive powers below 0.05 and are not described here.

3.2. Owner goals

The importance of different forest management goals (Fig. 1b) had been rated by the SPF owners on a 5-point Likert scale, and accordingly, we calculated R^2 scores to examine the predictive power of the random forest models. In general, predictions were rather unassertive. Among the 16 models, the average R^2 score was 0.039, and four goals reached predictive powers exceeding 0.050: *wood production for selling*; *wood production for personal consumption*; *profit maximization*; and *possibility for hunting*. The most important predictors for the goal of *wood production for selling* ($R^2 = 0.173$) were *agriculture/forestry* ($vi = 100$), followed by *total size* ($vi = 81$). 78.1 % of the agricultural or forestry professionals perceived the goal as important compared to 51.0 % of the other owners. Here and in the following, we use the term "important" to combine the Likert scores "rather important (4)" and "very important (5)", similar to Butler et al. (2017). Owners with a total forest size of more than 2.5 ha agreed with the importance of this goal in 70.2 % of the cases, compared to 48.3 % of the owners of smaller lots. Regarding *wood production for personal consumption* ($R^2 = 0.145$), the importance of this goal decreased with the *distance* ($vi = 100$) between the residence and the forest plot. 73.3 % of owners living within 10 km of their forest supported this goal, compared to 46.4 % of those living further away. *Settlement size* ($vi = 66$) also played a negative role, with 46.6 % of people living in places with more than 5000 inhabitants supporting this goal, compared to 73.3 % of people living in smaller communities. The goal of *profit maximization* ($R^2 = 0.104$) was important for 43.6 % of the agricultural or forestry professionals ($vi = 100$), while only 19.8 % of the other owners supported it. The goal *possibility for hunting* ($R^2 = 0.072$) reached the lowest predictive power out of all goals that still lie above 0.050, and was most strongly influenced by the variable *total size* ($vi = 100$). Owners of parcels larger than 2.5 ha considered this goal as important in 34.3 % of the cases, while owners of smaller properties did so in only 19.4 % of the cases.

3.3. Perceived obstacles

Several possible obstacles to the owners' goals (Fig 1c) had to be rated using yes/no answers in the questionnaire, and Cohen's kappa values were used to assess the models' predictive power. The average κ value among the response variables was 0.048, but only three out of 17 obstacles allowed for prediction using our determinant variables: *distance between forest and living place*; *lack of time*; and *forest size is too small.* All other models had κ values below 0.050 and are not considered in the following. The model for the obstacle *distance* ($\kappa = 0.408$) is the model with the highest overall predictive power and is uniquely dependent on *distance* ($vi = 100$). Forest owners who live more than 10 km from their forest perceived this distance as an obstacle to their management goals in 47.7 % of the cases, compared to 1.3 % of the owners who live closer. The model for *lack of time* ($\kappa = 0.255$) also showed a relatively high predictive power and depends on the variable *owner age* ($vi = 100$). Owners over the age of 65 reported a lack of time in only 19.9 % of the cases, while for younger owners, this obstacle hampered their management in 52.2 % of the cases. The model for the obstacle *too small* ($\kappa = 0.112$) was also dominated by the influence of a single predictor, *total size* ($vi = 100$). Owners of more than 2.5 ha of forest land perceived the size of their property as an obstacle in only 21.7 % of the cases, while for 46.9 % of the smaller-scale owners, property size was a limiting factor in their management. Other perceived obstacles could not be successfully predicted by our set of predictors.

3.4. Conservation attitudes

Attitudes toward various aspects of nature conservation (see Fig. 1d) were assessed by measuring individual agreement with 14 statements on a 5-point Likert scale. As for the importance of management goals, we aggregated the Likert scores "rather strong agreement (4)" and "very strong agreement (5)". The predictive power of the models for conservation attitudes was rather poor, with an average R^2 value of 0.040, and only five models reaching a threshold of $R^2 = 0.050$. The corresponding attitude statements were the following: *my forest provides no other benefit to me, which is why I promote nature conservation*; *nature conservation in my forest implies refraining from any use*; *I perceive the management restrictions as too strict*; *conservation in my forest creates high costs*; *conservation in my forest threatens my personal freedom of decision.* The model for the attitude *no other benefit* ($R^2 = 0.095$) showed influences of the variables *female* ($vi = 100$) and *total size* ($vi = 74$). Forest owners who identified as female agreed with this statement in 35.8 % of the cases, compared to 20.5 % for owners who identified as male. Owners of parcels larger than 2.5 ha were less likely to agree, with a percentage of 18.7 %, compared to 28.1 % of the owners of smaller-scale parcels. The attitude *refrain from use* ($R^2 = 0.085$) was equally influenced by the predictors *female* ($vi = 100$) and *total size* ($vi = 89$). While people who identified as female supported the statement in 13.0 % of the cases, 5.6 % of the male-identifying owners did so. In larger-scale owners, the statement found 4.3 % agreement, while smaller-scale owners agreed in 9.8 % of the cases. The attitude *restrictions too strict* ($R^2 = 0.084$) had a single most important determinant, *number of parcels* ($vi = 100$). Owners of multiple parcels supported the statement in 53.8 % of the cases, while 34.1 % of the single-parcel owners showed agreement. *High costs* ($R^2 = 0.083$) showed equally strong influences from three predictors, *total size*, *number of parcels*, and *agriculture/forestry*, while the attitude *threatens freedom* ($R^2 = 0.078$) was influenced mostly by *agriculture/forestry* ($vi = 100$) and *number of parcels* ($vi = 61$).

4. Discussion

The gender of small-scale private forest (SPF) owners is often considered an important driver of their management decisions. Consistent with a body of research using multifactorial models to explain owner activities, we analyzed the respective influence of six forest characteristics and seven owner demographic parameters, including gender. We used these variables to also predict owner goals, perceived obstacles, and conservation attitudes.

4.1. Prediction of management activities

Among our models predicting management activities, we found a large percentage of comparably strong models. This was in line with previous studies that have focused mostly on predicting forest owner activities such as timber harvesting in the past (Beach et al., 2005; Joshi and Arano, 2009; Kuuluvainen et al., 2014) and identified important influences, such as parcel size, timber prices, and owner education (Côté et al., 2016; Silver et al., 2015; Table 1). The questionnaire used for the current study asked for five of the six variables that have been most often identified as strong predictors of forest owner behavior (parcel size, profession, education, income, age, urbanity). In addition, we included the variables types of acquisition and gender, which were less important overall. Driving influences varied among our response variables, but we were able to identify recurring patterns:

(1) Seven management activities (*timber sale*; *reduction of damage due to logging*; *promotion of natural tree regeneration*; *protection of young plants against deer browsing*; *planting/promotion of introduced tree species*; *planting/promotion of native tree species*; *promotion of broadleaf trees in coniferous forest*) were strongly and positively dependent on the total size of forest owned. The activities in this group can be characterized as either classical or close-to-nature silvicultural activities (Tiebel et al., 2024), aiming at the maintenance and economic use of the forest. We found negative influences of the amount of broadleaf forest on *timber sale*, *planting/promotion of introduced tree species*, and *promotion of broadleaf trees in coniferous forests*, and conclude that these activities are preferred by owners of large parcels with predominantly coniferous forests. Owners' profession and the amount of time they spend in their forests also played a role as predictors, underscoring the business-related nature of these activities.

(2) A different pattern was found for a second set of activities (*protection of habitat trees*; *protection of dead wood*; *avoiding clearcuts*). These activities can be characterized as passive conservation and close-to-nature silvicultural activities according to Tiebel et al. (2024). They were preferentially practiced in broadleaf forests, while other predictors such as total size, number of parcels, or owner profession did not show noticeable influences here. Comparing our results with the literature (see Table 1), we were able to confirm the strong influence of parcel size on harvesting activity. Previously observed effects of owner profession were also seen in our data, but we could not support influences by age, education, or urbanity, which showed only very weak influences in our analyses. The only noticeable influence of gender was found when looking at the activity *harvest of single mature trees*, which did not fall into any of the groups described above, but was mostly dependent on being an agricultural or forestry professional.

4.2. Prediction of goals, obstacles, and conservation attitudes

In contrast to the strong models for management activities, only four of the surveyed owner goals were influenced by our predictors to a noticeable degree. Three of them (*wood production for selling*; *profit maximization*; *possibility for hunting*) showed a similar pattern as the economically oriented activities mentioned above, being mostly influenced by owner profession and parcel size. The fourth goal, *wood production for personal consumption*, was favored mostly by small-town dwellers (settlement size) and hindered by long distances to their forests, which is reasonable given the often family-based and local nature of self-sufficient firewood production (Warde, 2019).

The models of perceived obstacles to forest owners' management goals performed well in three cases, but provided little insight into the predictors of obstacles in general. The obstacles *distance between forest and living place* and *forest size is too small* were almost exclusively driven by the predictors distance and size, respectively. This was to be expected and at least validates our method. The obstacle *lack of time* was most strongly predicted by the age of the owner being younger than 65 years, suggesting that older and mostly retired people may not perceive a lack of time as an obstacle to their management. Again, this was to be expected to some extent, and other variables did not play a noticeable role in our analyses of obstacles to management goals.

The models of the response variable group of conservation attitudes scored relatively low on the scale of predictive power, but we found five above our threshold. It is interesting to note that these attitudes were not only influenced by the ubiquitous parcel size as well as number of parcels and profession, but that we also found influences of gender here, at least for the agreement with two statements (*my forest provides no other benefit to me, which is why I promote nature conservation*; *nature conservation in my forest implies refraining from any use*). Such a stronger support for conservation (Kuhlman et al., 2022; Tiebel et al., 2022; Umaerus et al., 2019), as well as higher passivity (Schlecht and Westermeyer, 2010) in female forest owners have been described in the literature. Coming into an inheritance late in a forest owner's life might play a role in explaining passive attitudes, and female forest owners are known to have inherited their property more often (Kuhlman et al., 2023). Regarding forest owners' attitudes toward conservation, Tiebel et al.

(2021) found differences related to the location of the owner's parcel inside or outside of protected areas. Policy instruments such as protection status, as well as other external factors such as market drivers have been shown to influence owners' activities (see Table 1), but were not the focus of the present study.

4.3. Gender differences

Gender differences in forest owner attitudes and behaviors have been the subject of much research (see Section 1 for an overview). Based on our results, we ask whether these differences call for different approaches when targeting female and male forest owners. Consistent with the existing literature (Floress et al., 2019; Husa and Kosenius, 2021; Silver et al., 2015), we found that salient behavioral variables were mostly indifferent to forest owner gender, and parameters such as goals, obstacles, and conservation attitudes showed mostly the same pattern among forest owners who identified as female and male. It is important to note that statistical differences by gender do not imply causality, nor do they support an understanding of innate "feminine" character traits or concepts (e.g., concepts such as *active forest ownership* are often misleadingly understood as "masculine" compared to "feminine" concepts such as *taking care* (Kuhlman et al., 2024)). Gender differences among the surveyed SPF owners may be indicative of an underlying context: Caputo and Snyder (2023) pointed out that absentee owners are less active. The commonplace that female-identifying owners are more passive may not be an innate female trait, but a sign of an underlying cause. For various reasons, such as more frequent inheritances, female owners tend to live farther away from their property, which makes active management more difficult (30.1 % of female owners in our dataset live more than 10 km away from their forest, compared to 16.1 % of male owners). Looking at the occupation of the owner (Pieper et al., 2023), we find that 16.3 % of female owners identify themselves as agricultural or forestry professionals, compared to 34.1 % of male owners. Strong influences of such professions (Hogl et al., 2005) on management choices such as the harvesting of single mature trees, as we have seen in our results, may also explain seemingly strong influences of gender. Therefore, we advocate for a thoughtful presentation of research results. The approach of analyzing correlations of gender as a single factor can provide detailed information about gendered distributions of attitudes, behaviors, knowledge, or assets among forest owners. However, great care must be taken to avoid giving the impression of causality between (stated or attributed) gender and variables such as attitudes or behavior (Agarwal, 1992).

4.4. Limitations and room for further research

The questionnaire used in the present study did not include some potentially interesting predictors, for example, on harvesting and other silvicultural behaviors. We also do not have data on the length of tenure (Côté et al., 2016; Kuuluvainen et al., 2014), which could be a proxy for the forest owners' emotional attachment to their property or feelings about forests as family heritage (Matilainen et al., 2019), or for their experience working in forests. Regarding financial influences, we did not control for market drivers such as timber prices, and we do not know the owners' income (Beach et al., 2005; Binkley, 1981; Husa and Kosenius, 2021; Joshi and Arano, 2009) or what percentage of their income comes from timber sales. We also cannot assess whether owners make all decisions about the forest themselves, or whether they rely on a forester, contractor, or friends or relatives for advice and practical management. Possible influences of these factors, also in comparison to the predictors we have already assessed, could be the subject of further studies. Other types of determinants could also be considered. Owners' goals have been used as factors predicting future behavior, although such a link between the owners' goals and concrete actions in their forests has been shown to be weak, with the authors arguing for owners' attitudes instead (Floress et al., 2019). Concerning the statistical methodology, the choice of random forest models for predictions was guided by their ability to provide measures for variable importance. Variable importance is known to spuriously depend on the number of categories of predictors, as described in Section 2.2, or on their scale of measurement (Strobl et al., 2007). We decided on downsampling our predictors to binary categorical variables to prevent this, thereby tolerating some information loss. Downsampling in similar contexts could be avoided in future research by careful consideration of alternative variable importance measures (Archer and Kimes, 2008; Strobl et al., 2007). While our research focused on identifying and evaluating predictors of behavior and attitudes of SPF owners, one must be careful not to interpret the findings as describing causal relationships. Further research work, possibly including the biographies of forest owners, will be essential to answer questions of causality.

4.5. Implications for outreach and conservation communication

When asked about their needs, SPF owners often express a desire for information, support, and empowerment in the practical management in their forests (Joa and Schraml, 2020; Paloniemi and Vainio, 2011). Especially female-identifying forest owners often express feelings of uncertainty and a greater wish for assistance (Berget and Dwivedi, 2024). Female networks can be a beneficial tool to empower those forest owners who feel marginalized in a male-dominated environment. Empowerment by such networks of peers can change the discourse in forestry, providing for alternative safe spaces (Andersson and Lidestav, 2016). Peer learning groups can also help people become more confident also in more diverse settings (Hamunen et al., 2020).

On the other hand, when planning outreach or policy instruments to promote nature conservation in SPFs, it is advisable to have a clear understanding of the target group in order to design carefully targeted interventions. The results of the current study, as well as the larger body of work dedicated to multifactorial analysis of predictors of forest owner activities (Silver et al., 2015; Floress et al., 2019; Husa and Kosenius, 2021; Table 1), suggest that projects specifically targeting female-identifying forest owners (Hafner et al., 2021; Lukacic et al., 2023) may not be the tool of choice when trying to influence forest owners' attitudes and behavior. Rather, a more precise analysis of the forest owner population, its characteristics and specific needs could increase the net benefit and efficiency of outreach to forest owners. Our results suggest to distinguish between the following two easily identifiable groups of forest owners when promoting conservation ideas:

(1) Ownership of large forest parcels has been shown to be an important predictor for a number of classical or close-to-nature silvicultural activities. Some owners already engage in activities that are beneficial from a conservation perspective, such as promoting natural tree regeneration (Larsen et al., 2022) or planting native broadleaf species. Owners of larger SPF parcels should be encouraged to continue or expand this behavior, while they may

need support and guidance with respect to the ongoing scientific debate on the planting of non-native or non-local tree provenances (Karrer et al., 2022; Pötzelsberger et al., 2020; Wessely et al., 2024). Owners will need to choose a transition strategy for their often conifer-dominated forests, and it will be important to point out that converting their forests toward mixed or broadleaf stands, although it may instinctively be opposed by some forest owners, is imperative given the climate trajectory and will also be economically beneficial in the long run.

(2) Our results show that owners of predominantly broadleaf forests often do the right thing from a conservation perspective. They protect habitat trees and deadwood in their forests and avoid clearcutting (Storch et al., 2020). These owners could be supported in their decisions. Education about the high conservation values already present in their forests could lead to even greater awareness (Baranovskis et al., 2022; Joa and Schraml, 2020; Thorn et al., 2020), and policy instruments could provide incentives for conservation measures (e.g., BMEL, 2022 for Germany), even in the face of more traditional forestry staff who promote forests' economic use.

5. Conclusion

Gender is often assumed to be an important driver of differences among small-scale private forest owners and the management decisions they make. We challenged this assumption by considering a larger set of easily accessible owner demographic variables as well as forest parcel characteristics. Analysis of questionnaire data from small-scale private forest owners allowed us to identify key predictors of different owner activities, as well as owner goals, perceived obstacles, and conservation attitudes. Strong models were built for important forest management activities, but also for different owner goals, obstacles to these goals, and, to a lesser extent, conservation attitudes. The predictors of our response variables varied, but some patterns emerged. Consistently, parcel size was a top predictor of many of our response variables, especially for economically important management activities, while broadleaf forest owners tended to have a more conservation-oriented management style. In general, owner gender was not an efficient predictor of our response variables. Peer networking and gender-specific outreach can still be great tools for empowering female-identifying forest owners, but in order to target communication to diverse groups, we argue for a set of readily available demographic and site characteristic variables that lend themselves to the design of outreach to forest owners. Careful target group analysis can lead to more individualized conservation outreach strategies in small-scale private forests that are embedded in the overall livelihood systems of their owners.

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CRediT authorship contribution statement

Peter Hansen: Writing – original draft, visualization, methodology, formal analysis, conceptualization. **Malin Tiebel:** Writing – review & editing, investigation. **Tobias Plieninger:** Writing – review & editing, investigation, funding acquisition. **Andreas Mölder:** Writing – review & editing, investigation, funding acquisition.

Declaration of competing interest

The authors declare no competing interests.

Appendix

Table A1
Details of the response variables.

Question	Nr.	Response range	Wording	Mean
Activity	1	0 or 1	Thinning	0.860
Activity	2	0 or 1	Protection of habitat trees	0.438
Activity	3	0 or 1	Protection of young plants against browsing	0.455
Activity	4	0 or 1	Reduction of damage due to logging	0.517
Activity	5	0 or 1	Avoidance of chemical pesticides	0.748
Activity	6	0 or 1	Coppicing/coppicing with standards	0.119
Activity	7	0 or 1	Wood pasture	0.014
Activity	8	0 or 1	Promotion of a shrub layer	0.106
Activity	9	0 or 1	Promotion of broadleaf trees in coniferous forests	0.435
Activity	10	0 or 1	Protection/restoration of light stand structures	0.232
Activity	11	0 or 1	Protection/maintenance of special structures	0.121
Activity	12	0 or 1	Use of logging horses	0.022
Activity	13	0 or 1	Timber sale	0.611
Activity	14	0 or 1	Planting/promotion of native tree species	0.645
Activity	15	0 or 1	Planting/promotion of introduced tree species	0.290
Activity	16	0 or 1	Promotion of rare native tree and shrub species	0.157
Activity	17	0 or 1	Promotion of natural tree regeneration	0.562

(*continued on next page*)

Table A1 (*continued*)

Question	Nr.	Response range	Wording	Mean
Activity	18	0 or 1	Avoiding clearcuts	0.657
Activity	19	0 or 1	Protection of dead wood	0.449
Activity	20	0 or 1	Harvest of single mature trees	0.476
Activity	21	0 or 1	Species protection measures	0.201
Activity	22	0 or 1	Pruning	0.158
Activity	23	0 or 1	Biotope restoration	0.046
Activity	24	0 or 1	Removal of introduced species	0.194
Activity	25	0 or 1	Non-use of parts of the stand	0.166
Activity	26	0 or 1	None	0.005
Goal	1	5-point Likert (1 to 5)	Collection of non-wood products	2.179
Goal	2	5-point Likert (1 to 5)	Possibility for own recreation	3.354
Goal	3	5-point Likert (1 to 5)	Wood production for selling	3.501
Goal	4	5-point Likert (1 to 5)	Wood production for personal consumption	3.772
Goal	5	5-point Likert (1 to 5)	Long-term preservation of a stable and healthy forest stand	4.729
Goal	6	5-point Likert (1 to 5)	Possibility for hunting	2.460
Goal	7	5-point Likert (1 to 5)	Safeguarding or enhancement of landscape beauty	3.898
Goal	8	5-point Likert (1 to 5)	Protection as a cultural asset	4.226
Goal	9	5-point Likert (1 to 5)	Carbon sequestration, conservation of carbon sinks	4.306
Goal	10	5-point Likert (1 to 5)	Biodiversity conservation	4.403
Goal	11	5-point Likert (1 to 5)	Preservation for financial security	3.311
Goal	12	5-point Likert (1 to 5)	Profit maximization	2.681
Goal	13	5-point Likert (1 to 5)	Preservation of family heritage	4.211
Goal	14	5-point Likert (1 to 5)	Protection of soil, water, air quality	4.498
Goal	15	5-point Likert (1 to 5)	Preservation as a place of education	3.384
Goal	16	5-point Likert (1 to 5)	Possibility for nature observation	3.806
Obstacle	1	0 or 1	No notable restrictions	0.291
Obstacle	2	0 or 1	Lack of time	0.405
Obstacle	3	0 or 1	Lack of money	0.201
Obstacle	4	0 or 1	Lack of technical equipment	0.193
Obstacle	5	0 or 1	Lack of skills	0.144
Obstacle	6	0 or 1	Lack of knowledge	0.221
Obstacle	7	0 or 1	Lack of information	0.129
Obstacle	8	0 or 1	Lack of family labor force	0.323
Obstacle	9	0 or 1	Forest size is too small	0.343
Obstacle	10	0 or 1	Unclear boundaries of the forest	0.056
Obstacle	11	0 or 1	Unknown contact persons	0.039
Obstacle	12	0 or 1	Poor accessibility through forest roads	0.081
Obstacle	13	0 or 1	Uncertainty about the location of the forest	0.016
Obstacle	14	0 or 1	Distance between forest and living place	0.100
Obstacle	15	0 or 1	Too much effort	0.113
Obstacle	16	0 or 1	Lack of interest	0.021
Obstacle	17	0 or 1	Initial stand conditions unfavorable for my objectives	0.041
Attitude	1	5-point Likert (1 to 5)	Structures with high conservation value are present in my forest	3.288
Attitude	2	5-point Likert (1 to 5)	My management ensures natural forest conditions	3.976
Attitude	3	5-point Likert (1 to 5)	Even without financial support, I am willing to promote nature conservation	3.442
Attitude	4	5-point Likert (1 to 5)	My forest provides no other benefit to me, which is why I promote nature conservation	2.573
Attitude	5	5-point Likert (1 to 5)	Nature conservation in my forest continues the family tradition	3.204
Attitude	6	5-point Likert (1 to 5)	Nature conservation in my forest implies refraining from any use	1.763
Attitude	7	5-point Likert (1 to 5)	Extraction of renewable resources is more meaningful than nature conservation	2.616
Attitude	8	5-point Likert (1 to 5)	Conservation in my forest can limit recreational uses	2.782
Attitude	9	5-point Likert (1 to 5)	Conservation in my forest prevents a visually beautiful impression	2.195
Attitude	10	5-point Likert (1 to 5)	Conservation in my forest threatens my personal freedom of decision	2.973
Attitude	11	5-point Likert (1 to 5)	Conservation in my forest creates high costs	2.884
Attitude	12	5-point Likert (1 to 5)	I do not perform management due to difficult forest stand conditions	2.153
Attitude	13	5-point Likert (1 to 5)	I would like to see higher involvement in decision making processes about conservation	3.397
Attitude	14	5-point Likert (1 to 5)	I perceive the management restrictions as too strict	3.400

Table A2
Distribution of response variables (activities, goals, obstacles, and attitudes) with respect to the predictors. For binary responses (activities, obstacles), the percentage of "yes" responses is given. For Likert responses (goals, attitudes), Likert scores "rather important (4)" and "very important (5)" are combined, and the percentage of those responses is given.

Question	Nr.	Forest age		Bought/ leased		Broad-leaf		Total size		Nr. of parcels		Distance		Forestry training		Female		Owner age		Prof. qualific.		Agric./ forestry		Time in forest		Settlem. size	
		0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Activity	1	81.1	87.8	85.6	87.5	88.4	84.7	79.8	92.4	78.9	91.7	87.6	79.9	85.8	90.7	88.0	78.5	87.3	83.9	88.6	85.1	83.4	92.3	80.0	88.8	88.6	80.4
Activity	2	39.8	45.2	38.5	58.3	32.8	50.6	38.7	49.0	40.4	46.5	45.5	36.8	42.9	57.0	46.4	33.3	45.2	41.3	44.8	43.4	41.5	49.2	34.4	48.1	45.3	40.5
Activity	3	54.0	42.6	41.8	55.4	47.1	44.5	35.7	55.3	37.9	51.3	46.6	40.6	44.8	54.7	47.5	37.4	45.4	45.8	42.9	46.6	41.9	53.6	32.8	51.1	47.3	41.5
Activity	4	47.5	53.2	51.1	53.3	57.1	48.5	39.8	63.6	43.9	57.7	52.7	47.7	51.4	55.8	52.7	47.6	53.9	47.8	51.1	52.0	48.2	59.8	41.3	56.4	52.0	51.0
Activity	5	76.1	74.3	74.4	75.7	69.9	77.7	77.4	72.1	77.0	73.0	75.3	72.4	74.8	74.4	75.0	73.6	77.3	70.1	76.9	73.9	77.3	69.1	74.9	74.7	73.9	76.8
Activity	6	14.9	10.9	11.8	12.2	13.1	11.2	10.7	13.1	9.1	14.0	13.0	7.1	11.3	19.8	12.4	9.8	11.5	12.7	11.4	12.1	10.2	15.7	7.9	13.7	12.5	10.6
Activity	7	1.6	1.4	1.4	1.4	1.9	1.1	1.6	1.3	1.6	1.3	1.3	2.1	1.5	0.0	1.6	0.8	2.1	0.2	1.1	1.6	1.4	1.5	1.0	1.6	1.3	1.8
Activity	8	17.4	8.2	9.2	14.2	6.4	13.1	10.7	10.4	9.8	11.1	9.4	15.5	10.2	15.1	10.8	9.8	9.6	12.3	7.9	11.7	11.4	8.8	8.2	11.6	9.9	12.1
Activity	9	48.4	41.9	40.6	51.3	50.8	39.1	37.8	49.3	40.3	46.0	43.1	45.6	43.1	50.0	44.3	40.2	41.7	46.9	42.4	44.0	42.2	46.6	37.2	46.4	42.8	45.1
Activity	10	22.0	23.6	23.5	22.3	24.7	22.3	20.7	25.7	21.3	24.6	23.7	20.9	23.1	24.4	22.8	24.8	22.8	23.9	22.0	23.7	24.4	20.4	23.6	23.0	23.5	22.4
Activity	11	12.4	11.9	11.1	14.8	11.0	12.7	10.7	13.4	11.1	12.8	12.3	10.9	11.2	24.4	12.8	8.9	12.7	10.9	11.4	12.3	11.9	12.4	8.7	13.6	12.0	12.1
Activity	12	0.6	2.7	1.4	4.3	2.7	1.9	1.9	2.5	1.6	2.6	2.4	1.3	1.9	7.0	2.2	2.4	0.6	5.1	3.0	1.9	2.0	2.6	1.5	2.5	2.3	2.1
Activity	13	50.6	64.7	60.7	62.3	74.9	52.7	46.6	75.6	48.5	70.8	60.3	64.9	60.7	66.3	62.7	54.5	61.2	60.9	57.6	62.6	55.7	73.5	52.3	65.0	61.6	60.1
Activity	14	73.6	61.4	60.9	74.2	65.8	63.7	55.8	73.2	57.2	70.1	65.4	60.7	64.0	70.9	66.1	57.7	66.5	60.9	61.7	65.7	63.1	67.8	53.8	69.2	65.7	61.9
Activity	15	32.0	28.0	27.5	33.0	41.1	21.6	18.3	39.7	22.8	33.8	30.1	24.3	28.0	43.0	30.6	22.4	29.1	28.8	27.7	29.6	24.3	39.7	20.8	32.7	30.0	26.8
Activity	16	24.5	12.7	11.6	26.7	13.3	17.2	12.2	19.2	12.0	18.5	15.9	14.6	14.7	29.1	16.4	12.6	14.6	17.6	12.5	17.0	14.3	18.8	9.5	18.5	15.5	16.2
Activity	17	49.4	58.6	53.4	63.8	53.7	57.8	45.8	66.6	47.2	63.1	58.2	47.7	55.3	68.6	58.6	46.3	57.4	54.0	54.9	56.8	52.4	64.9	41.8	62.6	58.8	50.5
Activity	18	56.2	68.9	63.7	71.0	53.1	73.4	65.6	65.8	68.3	63.7	66.5	62.3	64.7	79.1	67.6	57.7	66.7	63.8	68.2	64.7	64.9	67.5	60.5	68.0	64.8	67.8
Activity	19	45.7	44.6	41.6	53.6	35.1	50.9	44.7	45.0	48.8	41.9	44.3	47.3	43.8	59.3	45.0	44.3	46.7	41.5	43.2	45.6	45.3	43.8	41.0	46.6	44.4	45.9
Activity	20	32.9	52.5	45.6	52.8	44.6	49.4	39.8	55.3	38.3	54.7	49.7	38.5	47.0	55.8	51.4	31.7	48.5	45.8	47.8	47.4	39.9	64.9	36.9	52.3	50.2	41.5
Activity	21	23.0	19.1	16.7	29.3	14.9	23.3	20.2	20.0	19.9	20.3	21.5	14.2	19.5	27.9	20.7	17.5	19.0	22.1	20.7	19.9	18.5	23.7	15.4	22.2	20.9	18.3
Activity	22	23.6	13.1	13.7	21.4	17.6	14.6	11.2	20.3	11.8	18.8	16.8	11.3	15.7	17.4	17.5	8.5	16.0	15.4	16.3	15.6	13.8	20.4	8.7	18.9	17.4	12.1
Activity	23	5.3	4.3	3.7	7.0	5.4	4.1	4.6	4.6	4.2	4.9	4.9	3.3	4.4	7.0	4.8	3.7	4.0	5.6	3.3	5.1	4.3	5.2	2.1	5.7	4.1	5.7
Activity	24	20.5	19.0	16.4	27.5	19.5	19.3	16.7	22.0	16.4	21.7	20.7	13.8	18.4	33.7	20.6	14.2	18.2	21.7	17.4	20.2	16.8	25.3	10.8	23.2	20.7	16.5
Activity	25	16.5	16.7	15.5	19.7	13.7	18.4	16.3	17.0	17.7	15.9	16.2	18.4	16.3	20.9	16.4	17.5	16.7	16.5	12.5	18.3	17.2	15.5	12.6	18.5	15.9	18.3
Activity	26	0.3	0.5	0.5	0.3	0.6	0.4	0.9	0.0	0.7	0.3	0.4	0.8	0.3	2.3	0.4	0.8	0.2	0.9	0.3	0.6	0.5	0.5	1.0	0.2	0.7	0.0
Goal	1	15.2	11.7	11.8	14.8	11.6	13.2	13.0	12.3	11.8	13.2	12.5	13.0	12.9	9.3	10.8	20.3	12.2	13.4	14.1	12.0	14.5	8.2	11.0	13.3	12.2	13.7
Goal	2	57.5	50.8	49.4	60.9	50.4	53.8	52.6	52.4	50.3	54.2	54.4	44.4	52.8	48.8	52.8	51.2	52.3	52.9	57.6	50.4	54.2	48.7	46.9	55.0	52.0	53.6
Goal	3	55.3	60.7	60.2	56.8	66.8	54.7	48.3	70.2	49.4	66.9	60.4	54.4	58.5	70.9	61.7	49.2	58.3	61.2	60.9	58.7	51.0	78.1	50.3	63.3	61.7	53.9
Goal	4	60.9	70.7	66.0	74.2	61.0	72.6	63.3	73.1	61.4	73.4	73.3	46.4	67.7	75.6	71.8	53.3	71.8	61.6	72.6	66.4	64.5	76.5	58.2	72.7	73.5	56.2
Goal	5	96.0	97.4	96.6	98.0	96.3	97.5	95.6	98.4	95.3	98.3	97.2	96.2	97.0	97.7	97.2	96.3	97.1	96.9	97.8	96.7	96.4	98.5	95.1	97.8	96.9	97.2
Goal	6	25.5	27.4	27.2	26.1	23.4	29.0	19.4	34.3	22.6	30.2	29.1	17.6	26.1	37.2	27.9	22.8	25.2	29.9	28.5	26.2	22.3	37.4	19.2	30.3	29.3	21.4
Goal	7	74.8	71.6	72.2	73.0	69.3	74.3	73.0	71.8	74.1	71.1	73.0	69.9	72.8	66.3	71.1	77.6	72.0	73.2	75.3	71.2	73.0	71.1	69.7	73.6	73.0	71.1
Goal	8	84.5	84.2	84.7	83.2	84.6	84.1	85.0	83.6	85.6	83.3	84.5	83.7	84.5	81.4	83.5	87.8	82.9	86.8	87.2	83.1	84.5	83.8	81.3	85.6	84.7	83.5
Goal	9	86.3	85.3	84.9	87.2	85.3	85.8	85.9	85.2	85.2	85.8	85.7	84.9	85.8	82.6	84.9	88.2	83.4	89.5	88.9	84.2	85.6	85.6	83.6	86.4	85.3	86.1
Goal	10	91.0	90.3	91.0	89.0	88.2	91.9	90.2	90.7	89.3	91.4	91.3	87.0	90.6	88.4	89.8	93.1	91.0	89.5	90.2	90.6	90.3	90.7	88.2	91.5	90.6	90.2
Goal	11	45.7	48.2	45.2	53.9	51.9	44.9	39.3	55.7	41.0	52.6	48.1	45.2	47.5	48.8	48.5	43.5	46.5	49.6	51.1	46.1	41.8	60.6	38.7	51.5	50.2	41.5
Goal	12	23.3	28.3	26.9	27.5	33.6	23.0	19.0	35.1	21.7	31.2	29.2	18.0	26.9	29.1	28.7	20.3	24.6	31.5	32.9	24.7	19.8	43.6	17.7	31.2	29.8	20.9
Goal	13	80.4	84.6	87.3	73.3	83.6	83.5	79.6	87.4	81.1	85.4	83.9	82.0	83.6	82.6	84.2	80.5	82.9	84.6	84.0	83.3	81.2	88.7	81.0	84.6	86.1	77.6
Goal	14	91.3	92.8	93.1	90.7	92.3	92.5	91.3	93.5	91.3	93.3	92.7	91.2	92.6	90.7	92.0	94.3	91.7	93.8	93.5	92.0	92.2	93.0	89.5	93.7	92.0	93.3
Goal	15	49.1	48.0	46.8	52.2	46.7	49.2	48.7	47.9	47.0	49.2	48.1	49.0	48.3	47.7	46.8	54.5	46.0	52.5	54.1	45.9	49.8	44.8	41.8	51.1	47.7	49.5
Goal	16	67.4	68.3	67.0	71.0	64.3	70.4	68.1	68.0	66.7	69.1	69.3	62.8	68.2	66.3	66.7	73.6	68.4	67.4	69.8	67.3	71.0	61.3	63.3	70.2	66.7	71.1
Obstacle	1	34.2	27.4	28.6	30.4	25.3	31.4	30.3	27.9	32.8	26.3	31.8	17.6	29.1	29.1	29.3	28.5	24.5	37.5	35.9	26.3	28.8	29.9	21.5	32.5	30.5	26.0
Obstacle	2	37.3	41.5	40.7	39.7	45.2	37.5	34.0	46.9	33.3	45.9	39.7	43.5	40.3	43.0	41.8	35.0	52.2	19.0	28.8	45.2	38.3	45.4	42.3	39.6	40.5	40.5
Obstacle	3	19.6	20.3	21.8	15.7	25.9	16.5	17.4	22.8	17.9	21.8	20.3	19.2	20.3	17.4	19.6	22.4	22.8	15.2	18.8	20.7	19.1	22.4	22.3	19.1	20.2	19.8
Obstacle	4	17.1	20.1	19.7	18.3	21.6	17.9	19.4	19.2	19.3	19.3	18.9	21.3	19.7	14.0	18.2	24.0	21.3	15.6	18.2	19.8	20.3	17.0	24.6	17.0	19.5	18.8
Obstacle	5	15.2	14.2	15.0	13.0	14.1	14.6	14.5	14.3	15.1	13.9	12.4	23.0	14.7	10.5	10.8	29.7	14.8	13.8	12.2	15.3	17.6	7.2	22.6	10.8	12.5	18.8
Obstacle	6	20.8	22.5	22.8	20.3	24.1	20.9	23.9	20.3	20.8	23.1	19.6	32.6	22.7	14.0	20.0	30.9	24.9	17.0	19.0	23.3	26.8	11.3	34.6	16.5	20.5	25.8
Obstacle	7	10.9	13.5	12.9	12.8	13.5	12.5	13.3	12.4	12.9	12.8	12.2	15.5	13.3	7.0	12.5	14.2	13.7	11.4	12.2	13.1	14.1	10.1	17.4	10.8	11.8	15.2
Obstacle	8	32.0	32.5	33.8	28.4	38.2	28.8	27.2	37.5	27.5	36.0	32.3	32.6	32.7	27.9	31.5	35.8	32.6	31.9	29.9	33.3	31.0	35.3	34.9	31.2	32.8	31.2
Obstacle	9	30.4	35.6	35.4	31.3	29.7	37.2	46.9	21.7	39.9	30.0	32.7	41.4	34.4	32.6	34.0	35.8	33.5	35.7	29.9	36.1	35.7	31.2	45.6	29.3	34.8	33.2

(*continued on next page*)

Table A2 (*continued*)

Question	Nr.	Forest age		Bought/ leased		Broad-leaf		Total size		Nr. of parcels		Distance		Forestry training		Female		Owner age		Prof. qualific.		Agric./ forestry		Time in forest		Settlem. size	
		0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Obstacle	10	2.2	6.8	4.9	7.5	4.6	6.2	7.1	4.1	3.8	7.0	5.1	7.9	5.8	2.3	5.2	7.3	5.4	6.0	5.2	5.8	6.1	4.4	7.7	4.7	4.8	7.5
Obstacle	11	3.1	4.2	3.8	4.3	3.3	4.3	4.3	3.6	3.6	4.2	3.3	6.7	4.1	2.3	3.5	5.7	4.5	2.9	3.3	4.2	5.1	1.3	5.9	3.1	3.5	4.9
Obstacle	12	5.6	9.0	7.4	10.1	8.7	7.8	7.3	9.0	5.5	10.2	8.1	8.4	8.1	8.1	8.8	5.3	8.5	7.4	8.7	7.9	6.7	11.3	4.9	9.6	9.3	5.4
Obstacle	13	0.6	1.9	1.7	1.2	1.9	1.4	1.6	1.6	1.5	1.7	0.9	4.6	1.7	0.0	1.3	2.8	1.6	1.6	0.3	2.1	2.0	0.5	2.3	1.3	1.3	2.3
Obstacle	14	8.1	10.7	10.7	8.1	11.0	9.4	12.5	7.6	10.7	9.5	1.3	47.7	10.1	9.3	8.3	17.1	9.0	11.8	5.7	11.8	12.7	3.9	15.6	7.5	5.9	19.3
Obstacle	15	8.7	12.2	12.4	8.4	14.9	9.0	10.4	12.1	9.7	12.5	10.1	16.3	11.2	12.8	10.7	13.8	11.7	10.5	9.5	12.0	10.8	12.4	13.6	10.3	10.1	13.9
Obstacle	16	1.9	2.2	2.6	0.9	2.5	1.9	2.2	2.0	2.6	1.8	1.8	3.3	2.2	1.2	1.7	4.1	2.3	1.8	1.9	2.2	2.7	0.8	4.9	0.9	1.9	2.6
Obstacle	17	3.1	4.4	4.0	4.3	5.2	3.4	4.7	3.5	5.1	3.3	3.9	5.0	4.1	4.7	4.1	4.1	4.9	2.7	3.3	4.4	4.2	3.9	6.2	3.2	3.9	4.6
Attitude	1	49.4	43.6	41.4	54.8	38.2	49.2	44.7	45.4	44.4	45.5	44.8	46.0	44.9	46.5	45.4	43.5	44.8	45.5	42.9	45.9	46.1	42.5	40.0	47.3	45.0	45.1
Attitude	2	77.6	75.7	74.8	80.0	68.5	80.9	78.4	74.0	75.8	76.5	76.7	74.1	75.7	82.6	76.9	73.2	76.1	76.3	79.3	74.9	76.7	75.0	73.6	77.3	76.5	75.5
Attitude	3	57.5	52.7	51.9	59.4	50.8	55.9	56.2	51.7	58.1	50.8	53.5	55.6	53.8	55.8	53.3	56.5	54.4	53.1	54.1	53.9	57.8	45.1	53.1	54.3	52.3	57.7
Attitude	4	23.3	23.5	24.6	20.3	23.7	23.3	28.1	18.7	29.1	19.1	21.0	33.9	23.5	22.1	20.5	35.8	19.9	29.9	26.4	22.2	26.9	15.5	28.5	21.2	20.9	29.1
Attitude	5	38.2	46.5	46.0	40.0	42.9	45.3	42.8	46.0	43.0	45.5	44.1	45.6	44.6	41.9	43.5	48.0	43.2	46.7	46.5	43.6	44.3	44.6	42.1	45.4	43.3	46.9
Attitude	6	7.8	6.8	7.5	5.8	6.0	7.6	9.8	4.3	10.2	4.6	5.6	13.0	7.0	7.0	5.6	13.0	7.4	6.2	6.2	7.3	8.6	3.4	10.3	5.6	4.9	11.9
Attitude	7	19.6	22.6	21.9	21.7	21.0	22.4	19.4	24.3	19.1	23.9	22.7	18.0	21.7	23.3	22.6	18.7	20.7	23.9	23.6	21.1	16.8	33.2	16.4	24.3	22.8	19.6
Attitude	8	23.0	27.6	24.9	30.4	24.9	27.4	24.0	28.8	23.5	28.7	26.8	24.7	26.4	26.7	26.7	25.2	28.0	23.4	25.3	26.9	25.0	29.6	25.4	26.9	26.1	27.1
Attitude	9	11.8	12.4	11.9	13.0	12.4	12.1	10.0	14.5	9.5	14.3	13.0	8.8	12.5	8.1	13.3	7.7	11.1	14.3	14.9	11.1	9.5	18.3	9.7	13.3	13.8	8.8
Attitude	10	30.4	42.0	38.7	40.0	38.6	39.3	31.4	46.6	31.9	44.5	41.2	29.7	38.8	41.9	43.1	22.4	40.2	36.8	41.0	38.2	32.4	54.1	34.1	41.2	40.9	34.8
Attitude	11	24.2	32.7	30.7	30.1	32.6	29.3	22.0	39.1	22.0	37.0	32.0	24.3	30.5	31.4	33.0	20.3	31.6	28.6	29.1	31.1	24.4	44.3	22.6	34.1	32.8	25.3
Attitude	12	16.8	15.6	16.4	14.8	14.9	16.5	16.1	15.7	17.1	15.0	14.1	23.8	15.8	17.4	14.4	22.4	14.9	17.9	16.3	15.8	16.1	15.5	19.0	14.6	15.9	16.0
Attitude	13	49.7	52.3	49.5	57.4	51.0	52.0	48.5	54.8	46.6	55.5	52.0	50.2	51.4	55.8	53.1	45.5	53.9	47.5	49.5	52.6	49.9	55.7	46.7	53.9	51.0	53.1
Attitude	14	33.5	49.3	44.9	46.4	46.3	44.7	37.6	52.9	34.1	53.8	46.9	38.1	44.9	50.0	48.1	33.3	47.7	40.8	42.1	46.6	40.2	56.7	38.5	48.3	47.5	40.2

Data availability

All data used in the scope of this article as well as the detailed variable importance results can be found on the platform Zenodo by using the following link: https://doi.org/10.5281/zenodo.13354267.

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