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ORIGINAL RESEARCH

Forest Owners' Intentions to Implement Environmentally Oriented Forest Management Practices: A Case from Eastern Finland

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Abstract
Forests and forest management are crucial in achieving environmental objectives, including mitigating climate change by sequestering carbon, preserving biodiversity, and preventing the eutrophication of surface waters. Achieving environmental objectives heavily depends on the willingness of private forest owners to adopt environmentally oriented forest management practices (EFMPs). This study investigates private forest owners' intentions to implement specific EFMPs, including increasing the proportion of deciduous trees, ash fertilization on peatlands, extending rotation periods, implementing continuous cover forestry, and adding deadwood and retention trees. Guided by the theory of planned behavior, we explore how Finnish forest owners' beliefs about EFMPs, attitudes towards environmental objectives, subjective norms (SN), and perceived behavioral control (PBC) influence their intentions to implement EFMPs. A postal survey was conducted among forest owners in the Lake Puruvesi region of eastern Finland (n = 102). The data were analyzed using structural equation models (SEM). The findings indicate that forest owners generally have evident intentions to implement EFMPs. ATT towards environmental objectives had the strongest positive impact, while SN and PBC had no significant influence on the intention to implement EFMPs. The findings suggest that in promoting EFMPs, policy efforts should focus on evidence-based information regarding water protection and biodiversity impacts. Forest owners' attitudes and subjective norms concerning carbon sequestration are less prominent compared to their views on water protection and biodiversity.

Keywords Sustainable forest management · Forestry practices · Forest owners' perceptions · Forest management decision-making

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Introduction

Forests play a crucial role in mitigating climate change by sequestering carbon and reducing emissions through the substitution effects of wood products (Gustavsson and Sathre 2011), while also providing various essential ecosystem services (Millennium Ecosystem Assessment 2005). However, industrial-scale harvesting and forest management significantly contribute to biodiversity degradation in boreal forests (e.g. Savilaakso et al. 2021) and the deterioration of other sensitive ecosystems, such as the eutrophication of surface waters (Laudon et al. 2011; Shah et al. 2020). Balancing these environmental objectives, coupled with the complex interplay of economic considerations (Mazziotta et al. 2023; Mäntymaa et al. 2023), presents significant challenges for the current practices of forestry. Particularly in countries where private ownership prevails, achieving society's environmental goals heavily depends on the willingness of private forest owners to adopt environmentally oriented forest management practices (EFMPs).

There is a growing body of literature exploring various EFMPs to address these global challenges and better align forestry with the United Nations Sustainable Development Goals (e.g. Peura et al. 2018). In the boreal zone, for example, conventional even-aged rotation forest management (i.e. clear-cut forestry), which has been a prevalent forest management practice for several decades, is being challenged by continuous cover forestry (CCF) to promote more sustainable forestry. Researchers have observed that the application of CCF, especially in drained peatlands, could have the potential to increase carbon sinks (e.g. Lehtonen et al. 2023). Moreover, recent studies have increasingly focused on other environmentally oriented forest management methods, such as those explored by Triviño et al. (2015) and Felton et al. (2016). For example, extending the rotation period is a promising approach to sequester carbon (Liski et al. 2001; Triviño et al. 2015), while increasing the amount of decaying wood (Roberge et al. 2016) and the proportion of deciduous trees (Huuskonen et al. 2021) is expected to increase biodiversity. Additionally, an increase in overall production levels and enhancement of the availability of various ecosystem services (i.e. a multi-objective approach) might be achieved by combining different management strategies and practices (Peura et al. 2018; Díaz-Yáñez et al. 2019, 2021; Triviño et al. 2022).

Within the European Union, approximately 60% of all forests are under private ownership (European Commission 2013). The majority of these privately-owned forests are held by non-industrial private forest owners (Živojinović et al. 2015; Schmithüsen and Hirsch 2010). In regions where private ownership dominates, as is the case in Finland where 60% of productive forest land is privately owned by individuals, private forest owners have relatively significant freedom to make decisions regarding forest management within the legal framework The 2014 reform of the Forest Act expanded this freedom by promoting more diverse forest management, including, for example, the option to practice continuous cover forestry through the removal of age and diameter limits for regeneration (Finlex 2013). Against this backdrop, the transition towards EFMPs necessitates an understanding of the multifaceted decision-making processes undertaken by private forest owners, who play a pivotal role in shaping forest use and management (Pynnönen et al. 2018; Joa and Schraml 2020; Husa and Kosenius 2021).

Motivations and objectives are essential factors influencing the forest management decisions of private forest owners (e.g. Kuuluvainen et al. 1996; Finley and Kittridge 2006; Ní Dhubháin et al. 2007). Beyond mere emphasis on timber production, owners' objectives and management strategies encompass, for example, recreational, economic security, and biodiversity values, often mixing multiple aspects and considerations (see e.g. Blanco et al. 2015; Feliciano et al. 2017; Ficko et al. 2019; Westin et al. 2023). Pynnönen et al. (2018) found that a significant proportion of forest owners in Finland are willing to integrate economic and other ownership objectives rather equitably.

Although numerous European studies have explored the factors that influence forest management decisions in Europe (e.g. Karppinen 1998; Follo et al. 2016; Eriksson and Fries 2020; Westin et al. 2023), and several policy instruments have been developed to influence forest owners' decisions towards more sustainable forest management practices (e.g. Vedel et al. 2015; Juutinen et al. 2021), research on forest owners' intentions to implement EFMPs remains relatively scarce. In Finland, as multi-objective forest management is not yet a standard practice in planning and advisory services (Pynnönen et al. 2018), more understanding of private forest owners' intentions to implement EFMPs and the underlying reasons is also needed to guide the design of forest policy measures.

In this study, we apply a widely used theory from social psychology, the theory of planned behavior (TPB) (Ajzen 1985, 1991; Ajzen and Driver 1992), to understand forest owners' intentions to implement EFMPs, with a focus on private individual forest owners in the Lake Puruvesi region in Eastern Finland. A few previous studies have demonstrated how forest owners' intentions regarding forest management practices are formed based on their beliefs, attitudes, social norms, and perceived constraints (Bieling 2004; Karppinen 2005; Thompson and Hansen 2013; Karppinen and Berghäll 2015; Holt et al. 2021; Koskela and Karppinen 2021, 2024). Our study differs from these previous TPB studies by integrating several EFMPs. Unlike previous studies, we recognize the diverse environmental objectives of forest owners that associate with their beliefs concerning the outcomes of management practices.

Grounded in TPB, we aim to investigate forest owners' intentions to implement specific management practices based on environmental objectives, focusing on carbon sequestration, water protection, and biodiversity. We seek to analyze whether forest owners' attitudes toward these environmental objectives, their subjective norms, and their perceived behavioral control influence their intentions to implement selected management practices. The practices under consideration include increasing the proportion of deciduous trees, ash fertilization on peatlands, extending rotation periods, implementing CCF, and adding deadwood and retention trees in forests. Furthermore, we explore respondents' beliefs regarding the potential of these management practices to promote the environmental objectives.

Theoretical Background

TPB has been employed across various disciplines to examine the social-psychological factors and antecedents influencing individual behavior (Ajzen 1987, 1991). Among the several theoretical approaches used to understand and predict forest owners' management actions, TPB is particularly promising, as it focuses on behaviors that are well considered, much like forest management decisions. The TPB framework can reveal the drivers and barriers to the adoption of forest management practices by forest owners.

According to TPB, a greater intention to adopt a practice corresponds to a higher likelihood of translating this intention into action. For example, Sheeran's (2002) meta-analysis of ten previous meta-analyses reported correlations between intentions and behaviors, ranging from 0.40 to 0.82, with an average of 0.54. In the research literature, intentions have been used to predict a wide range of behaviors, such as academic activities and achievement (Manstead and van Eekelen 1998), smoking (Norman et al. 1999), and cancer screening attendance behaviors (Sheeran and Orbell 2000).

Intention is determined by attitudes towards the action, subjective norms, and perceived behavioral control (Ajzen and Fishbein 1980; Ajzen 1987, 1991). According to TPB, the intention of a forest owner to adopt a practice is determined by the degree to which implementing it is evaluated positively or negatively by the forest owner (attitude, ATT), the feeling of social pressure from others (called referents) to adopt the practice (subjective norm, SN), and the beliefs of the owner about the ease or difficulty of successfully implementing a management practice, i.e., the degree to which a person believes the decision to be under his or her own control (perceived behavioral control, PBC). By combining ATT, SN, and PBC, a stronger or weaker intention to actually perform the behavior is obtained. The attitude towards a behavior is a product of behavioral beliefs about the impact of performing the behavior in question and the evaluation of the importance of the outcomes for the individual. The subjective norm is a product of normative beliefs and the motivation to comply. Perceived behavioral control is a product of control beliefs, i.e., a person's beliefs about the factors that support or inhibit the performance of the behavior, and the evaluation of how strongly the person perceives the controlling factors to affect the ease or difficulty of performing the behavior (Ajzen 1985, 1991; Ajzen and Driver 1992; Ajzen and Madden 1986).

In the context of forest management, TPB has been applied to predict several management intentions and behaviors. The theory has been used to examine different management regimes, such as close to nature forest management (Bieling 2004) and restoration forestry (Lima and Bastos 2020). It has also been employed to understand engagement in management practices supporting various environmental objectives, such as those supporting biodiversity (Koskela and Karppinen 2024). Koskela and Karppinen (2024) demonstrated that forest owners emphasized the components of PBC in their management decisions that were less driven by ATT and SN. In the case of providing carbon storage, Thompson and Hansen (2013) extended TPB but found PBC to have the strongest relationship with behavioral intentions.

Regarding economically oriented forest management, other factors of TPB have had explanatory power. Forest owners' choice of reforestation method was mostly affected by attitudes and past behavior (Karppinen 2005). In conducting timber stand improvement, Karppinen and Berghäll (2015) determined that the subjective norm was the strongest explanatory factor for forest owners' intentions. Normative pressures also had the greatest influence on the intention of landowners to harvest trees threatened by invasive insects (Holt et al. 2021). Furthermore, Fielding et al. (2005) demonstrated that stronger perceived normative support for riparian zone management was related to a stronger intention of landowners to implement this practice.

Koskela and Karppinen, (2024) also included behavioral, normative, and control beliefs in their study on forest owners' intentions to safeguard forest biodiversity, finding behavioral beliefs to have particular importance. Thompson and Hansen (2013) measured the corresponding beliefs and used them as additional measures of ATT, SN, and PBC in a structural equation model (SEM) for extended TPB. Regarding water protection, Fielding et al. (2005) demonstrated that individuals with strong intentions to engage in water protection rated the benefits of riparian zone management much more positively and the costs much less negatively compared to those with weak intentions. A similar association was also observed for normative beliefs and control beliefs.

In this study, we apply ideas of TPB to a combination of forest management practices that enhance the environmental objectives of carbon sequestration, water protection, and biodiversity. As engagement in environmental forest management is a complex decision for forest owners that involves several environmental objectives, as well as beliefs regarding the outcomes of practices, we test two approaches to build a model (Fig. 1). In Model 1 the intention to implement EFMPs is defined by the ATT, SN, and PBC to enhance each of the environmental objectives involved. In Model 2 we further test an extension of Model 1 by connecting beliefs regarding the outcomes of the management practices to the intention to implement them via ATT, SN, and PBC regarding the objective.

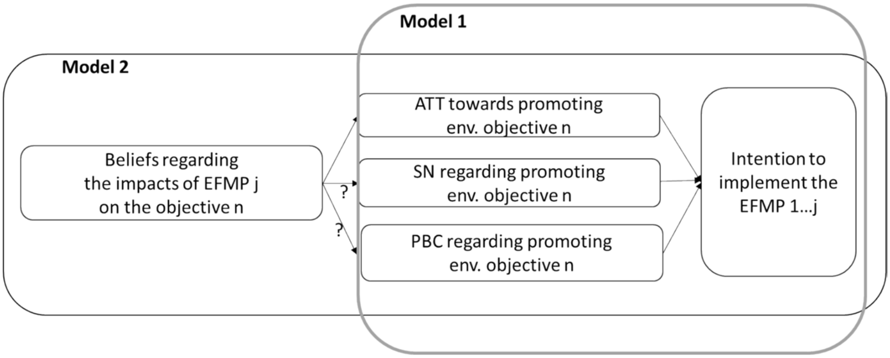


Fig. 1 The intention to implement environmentally oriented forest management practices (EFMPs) (1…j) based on attitudes (ATT), subjective norms (SN), and perceived behavioral control (PBC) regarding the environmental objectives (1…n) (Model 1) and further on the beliefs regarding the outcomes of the practices (1…j) (Model 2)

Case Area and Environmentally Oriented Forest Management Practices

The Case Study Area

To test our models, we selected a forested, mostly privately owned case area with several previously identified environmental goals. Lake Puruvesi, situated in eastern Finland, spans an area of 416 square kilometers. It exhibits oligotrophic characteristics, boasting clear water and a low humic content. A substantial proportion of the lake, amounting to 77% of its total area, is located within the Natura 2000 network and is actively utilized for recreational purposes, as documented by Tienhaara et al. (2021). Despite the generally excellent water quality of the lake, heightened nutrient (nitrogen, N, phosphorus, P) and suspended solid loads have been observed in shallow bay areas during intense rain periods and snowmelt in the spring. This has resulted in eutrophication and a deterioration in water quality in these specific areas.

The lake's catchment area, covering 1,017 square kilometers, is predominantly comprised of boreal forests, which occupy 92% of the land area and thrive on both mineral and organic (peatland) soils (Operandum project 2018–2022). Boreal forests in Finland consist of a mix of spruce, pine, and birch. These forests are predominantly managed as even-aged stands, with rotation forest management practices that have rotation lengths ranging from 40 to 120 years, depending on local conditions and forest types (Valsta 2017). In the case area, most of the surrounding forests are privately owned. The water quality challenges originate to great extend from forestry activities, particularly the former ditching of peatlands, maintenance of the ditch network, and clear cuttings of forests. In addition to the recreational use of forests and water quality issues, regional forest programs (Regional forest programs 2021–2025) aligned with national strategies (National Forest Strategy 2025) have emphasized the mitigation of climate change and conservation of biodiversity.

Overall, the Puruvesi region presents a compelling case study area due to its multifaceted significance. The forests are crucial for the regional economy and require sustainable management practices. Simultaneously, the presence of ecologically sensitive areas within the lake necessitates strategies to minimize the impact of forestry on water quality.

Selecting Environmentally Oriented Forest Management Practices

The EFMPs for the study were selected in cooperation with forest management experts and modelers. The characteristics of the area provided baseline information. The practices chosen were expected to be particularly relevant to the case area, with the aim of mitigating climate change, providing positive impacts on the region's aquatic ecosystems, and supporting biodiversity, or achieving combinations of these diverse environmental goals (e.g. Leinonen et al. 2023; Salmivaara et al. 2023). The potential management practices were *increasing the proportion of deciduous trees, ash fertilization of peatlands, extended rotation periods, CCF,* *and adding deadwood and retention trees.* These practices were further evaluated based on a literature review.

Increasing the proportion of deciduous trees has been found to have positive effects on biodiversity, such as increasing species diversity and the number of habitats (e.g. Huuskonen et al. 2021), although they do not improve living conditions per se for those endangered species that require old forests and dead wood. Furthermore, the vitality and improved risk management of mixed forests (e.g. against root rot and bark beetles) (Jactel et al. 2009, 2017) also ensure carbon sinks and stores. Potential risks include damage from browsing animals and diseases and pests present in several different tree species, which may proliferate more effectively (Huuskonen et al. 2021).

Ash fertilization of peatlands was selected as a long-lasting and effective way to enhance the growth of the forest stand at the right growing site (Haveraaen 2019), especially in peatland forests. Since drainage causes sediment, nutrient, and humus loading to water bodies (Nieminen et al. 2005), ash fertilization has emerged as a viable approach to alleviate the demand for ditch restoration in peatlands (Huotari et al. 2015). Ditch maintenance, in particular, is generally considered the most harmful forestry practice for water bodies (Nieminen et al. 2005; Finér et al. 2010). In Finland, for example, there is a potential to significantly increase the practice of ash fertilization beyond current levels (e.g. Moilanen et al. 2015; Lehtonen et al. 2021).

Extending rotation periods was included as one of the options, as it has been investigated as an effective management strategy for maintaining forest carbon storage by prolonging the period during which the forest stores carbon (see e.g. Liski et al. 2001; Triviño et al. 2015). However, this management approach primarily focuses on keeping the forest's carbon storage higher for a longer period, rather than increasing the forest's carbon uptake. Additionally, it offers the potential to enhance biodiversity by increasing, for instance, the availability of older trees and deadwood (Ranius et al. 2003; Roberge et al. 2016). However, optimizing carbon storage with the use of extended rotations has a trade-off, as it simplifies the forest structure and reduces the variety of species, thus decreasing the ability of forests to adapt to climate change (D'Amato et al. 2011).

Particularly in drained peatland areas, CCF might represent a viable management alternative in terms of both economic and environmental perspectives (Nieminen et al. 2018); in an optimal situation, there are no regeneration costs, and it has the potential to reduce nutrient and sediment loading compared to clear-cutting. Moreover, in CCF, the groundwater level can be regulated by adjusting the number of harvested trees, which can influence greenhouse gas emissions and also ensure sufficient evaporation from the forest floor, thereby reducing the need for ditch restoration or avoiding it altogether (e.g. Leppä et al. 2020). With CCF, forest biodiversity can also be improved to some degree, even though the method does not necessarily generate large amounts of deadwood (e.g. Peura et al. 2018; Duflot et al. 2022).

Adding deadwood and retention trees was selected because the practice is considered as a crucial feature to support biodiversity in commercial forests (see e.g. the review of Jonsson et al. 2005). In boreal forests, decaying wood also preserves carbon for long periods of time (Stokland 2021). According to Ranius et al. (2003), preserving small areas with living trees is an effective method to enhance the average amount and continuous presence of coarse woody debris.

These five management practices were identified as potential EFMPs and were included in the survey design to test forest owners' implementation intentions.

Survey Data and Statistical Methods

Sample and Survey Implementation

The sample of the study consisted of forest owners in the Puruvesi region that have particular importance for water protection. The approximate coordinates of the study area are 61.81°N, 29.35°E, representing the central location of the region. The previously conducted Operandum (2018–2022) (https://www.operandum-project.eu/) project provided a detailed description of the environmental and social conditions of the Puruvesi region. In the sample area, there were 501 forest owners who owned a total of 9,563 hectares of forest. Their contact information was obtained from the register of Finnish Forest Center.

To attain a representative sample of forest owners, we decided to use a postal survey because email addresses supporting an electronic survey were only available for some of the forest owners. An external research organization, Taloustutkimus Oy, conducted the survey in two parts.

In March 2023, the survey questionnaire was initially sent only to forest owners in one sub-catchment (n = 162). Ten days after the initial mailing, a reminder email was sent to the 76 forest owners for whom email addresses were available. Twenty days after the email reminder, at the end of April, a second postal survey was sent to the 133 individuals who had not yet responded. By the end of this process, a total of 39 forest owners had returned the survey. This first phase served as a pilot test for the survey measures.

To address the limited sample size in the first phase, the second phase of data collection expanded the survey by sending the same questionnaire to forest owners in two additional sub-catchments (n = 339). The questionnaire with cover letters was mailed to 339 forest owners in July 2023. The survey was remailed a month later to the 316 forest owners who had not responded by that time. For owners for whom an email address was available (135 forest owners), an email reminder to respond to the survey was sent at the end of August. A total of 63 individuals returned the survey form by the beginning of October 2023. After these two data collection phases, the survey datasets (n = 39 and n = 63) were combined, resulting in a final response count of 102 forest owners, forming a response rate of 20.4%.

Survey Design and Measures

The survey questions and statements were designed based on individual interviews with 22 local forest stakeholders, including forest owners, conducted in autumn 2022 (see Ukonmaanaho et al. 2024). In the open-ended interview questions, we asked about the current state of forestry in the region and expected changes. We asked respondents about their perceived objectives for forestry and their wishes for changes in forest management. We also posed questions about the factors that might enhance or hinder the actualization of the objectives. The respondents defined the key groups they perceived to impact on forest management and their own personal networks in forestry. Therefore, we utilized the responses obtained from the interviews in forming the statements. Beyond these interviews, we obtained additional insights from previous literature on TPB studies (e.g. Karppinen 2005; Karppinen and Berghäll 2015; Koskela and Karppinen 2024) and past surveys of forest owners (e.g. Karppinen et al. 2020).

In the first part of the questionnaire, the socioeconomic background of the respondents (gender, age, education, professional status, and owner's education in forestry or agriculture), the forest property features, such as the ownership type of the property, and the number of forest hectares was surveyed. In addition, the use of paid advisory services, information sources on environmental matters related to the forest property, and environmental subsidy agreements was inquired. In the second part, the forest owners' objectives and intentions to use environmentally oriented forest management, as well as related beliefs, attitudes, subjective norms, and behavioral control were measured. In the third part of the questionnaire, forest owners were asked to provide their perceptions regarding collaboration in forestry, but these results are reported elsewhere (Ukonmaanaho et al. 2024; Häyrinen et al. 2025).

To analyze the representativeness of the data, the respondents were compared with the respondents of a comprehensive national forest owner survey (Karppinen et al. 2020) and with forest owners in the South Savo region received from the statistical system of the Finnish Forest Centre. According to this comparison, both in this survey and in the Finnish Forest Owner 2020 survey (see Table 1), the gender distribution and the average age closely corresponded. In terms of age classification, however, the respondents in our study leaned slightly towards the older age groups. Furthermore, the level of education was similar in the surveys, although respondents were slightly more highly educated in our study (Table 1). In addition, compared to the forest owners in the South Savo region, the average age of our survey respondents was slightly higher (63 vs. 60 years) and they owned more forest on average (51 vs. 27 hectares) (Statistics of Finnish Forest Centre 2024).

The second part of the questionnaire used here measured the *intention* (INT) to implement EFMPs, i.e., five different forest management practices (increasing the proportion of deciduous trees, ash fertilization of peatlands, extended rotation period, CCF, and adding deadwood and retention trees). The measure of intention was obtained by asking to what extent the respondent had experience with the different practices, which was rated on a four-point scale (1 = I have used, but no longer use, 2 = I have used and will continue to use, 3 = I have not used, but plan to use in the near future, 4 = I have not used and do not plan to use). In the analysis phase, the four-point scale was converted to a dichotomous variable (if 2 or 3 then 1, if 1 or 4 then 0), for which a summative variable obtaining values from zero to five was created.

The environmental objectives were integrated in the questionnaire via measures of ATT, SN, and PBC. The *attitudes* towards three different environmental

Table 1 Descriptive statistics for the respondent characteristics compared to the sample of the Finnish Forest Owner 2020 survey

Characteristics	Current survey	Finnish Forest Owner 2020 survey
Average age, years	63	62
Age group %		
Under 45	16	12
45–54	11	14
55–64	17	23
65–74	38	33
75 or older	19	17
Gender %		
Female	25	24
Male	75	76
Educational level %[a]		
Comprehensive school	21	28
Vocational school (inc. agricultural schools and courses)	23	27
University of applied sciences or university	48	45
Other	8	–
Form of land ownership %[a,b]		
Individual or with spouse	74	83
Private partnership	18	9
Heirs	3	8
A limited company	2	–
Other form of ownership	4	–
Average forest area, hectares[a]	51	48

[a]Educational level, form of land ownership and average forest area are not directly comparable due to slightly different categorization

[b]In Finland, private individuals own 52% of forest land, including 60% of productive forest land. The state owns 35% (25% of productive forest land), companies 8% (8%), and municipalities, parishes, and communities 6% (6%) (Metsätilastollinen vuosikirja 2022). Private ownership is further categorized as shown in the table (form of land ownership)

objectives in forestry (carbon sequestration, water protection, biodiversity) were measured by asking respondents if they agreed the importance of these objectives in their forest management on a five-point Likert scale (1 = completely disagree, 5 = completely agree).

Subjective norms were measured on a Likert scale of 1 (completely disagree) through 5 (completely agree) with three statements by inquiring views on whether people important to them in forest matters believe that they should enhance 1) carbon sequestration, 2) water protection, and 3) biodiversity in forests.

Perceived behavioral control was measured with a Likert scale of 1 (completely disagree) through 5 (completely agree) using three different statements, inquiring whether the respondent believed they could enhance carbon sequestration in their forests, improve water protection, and increase biodiversity in their forests.

The *beliefs* regarding the outcomes of EFMPs were measured using three sets of five items. Each set assessed the respondent's evaluation of the effect of forest management practices on a specific environmental objective: carbon sequestration, water protection, or biodiversity. The five items in each set measured the same belief related to the respective environmental objective, evaluating the extent to which the respondent believed that the given forestry practice either improved, maintained, or did not affect the objective. Responses were measured on a five-point Likert scale (1 = does not affect, 5 = significantly improves), supplemented with the option to respond 'I can't say.' Normative and control beliefs were not measured to avoid respondent overload and because in previous studies on environmentally oriented forest management, especially behavioral beliefs have had importance (Koskela and Karppinen 2024). Additionally, behavioral beliefs have also found to be important for the planning the content of advisory services to enhance the behavioral change among forest owners (Häyrinen et al. 2025).

Statistical Modeling

To gain a deeper understanding of the factors influencing landowners' intentions to implement EFMPs, we first present a descriptive analysis of their intention to implement EFMPs and ATT, SN, and PBC regarding carbon sequestration (CS), water protection (WP), and biodiversity conservation (BC), as well as beliefs concerning the outcome of these forest management practices for CS, WP, and BC.

For a deeper analysis of intentions, we utilized SEM due to its numerous advantages over other regression models. SEM allows evaluation of the complete model while accounting for multiple dependent variables, making it the most effective method for analyzing the connections between the variables. SEM enables researchers to control for measurement error when using latent constructs, simultaneously examine path coefficients (β), assess the overall fit between the data and the hypothesized model, and more easily test for mediating relationships between variables compared to traditional methods (Blanthorne et al. 2006).

The correlation matrix between the key variables was calculated using Pearson's correlation coefficients ("Appendix 1"). Normality tests, such as relative multivariate kurtosis and the Mardia-based kappa, along with residual plots were used to evaluate multivariate normality. The full information maximum likelihood (FIML) estimation method was employed to account for the small number of respondents with a few missing answers. 'I can't say' responses were omitted from the structural equation analyses.

In the model estimation process, we started with the Model 1 and Model 2 (Fig. 1, "Appendix 2") by omitting non-significant measures for beliefs, ATT, SN, and PBC to obtain the final models. Modification indices were not used to improve the model fit. The explanatory power of the models can be assessed through standardized error variances, which indicate the proportion of variance not accounted for by the model. Additionally, we tested the effect of three dichotomous control variables (gender (male or female), forest ownership size (under or at least 50 hectares) and use of paid forest advisory services (yes or no). These control variables were added to Model 1 to assess their impact on the model's outcomes.

The goodness-of-fit measures of the models were utilized, including the comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). According to Hu and Bentler (1999), a reasonable fit is indicated by CFI $\geq$ 0.90 and a good fit by CFI $\geq$ 0.95. Correspondingly, SRMR and RMSEA values $\leq$ 0.08 are considered reasonable fits, while RMSEA $\leq$ 0.05 indicates a good fit. We also reported the model chi-square statistic along with its degrees of freedom and p-value to provide a comprehensive evaluation of model fit (Kline 2023). Statistical analyses were conducted using the CALIS procedure of SAS Enterprise Guide 7.15 (SAS Institute, Inc., Cary, NC, USA).

Results

Descriptive Statistics of the TPB Variables

Among the EFMPs queried (Fig. 2), the great majority of respondents intended to use the practice of *increasing the proportion of deciduous trees* in the future (80%). *Adding deadwood and retention trees* was also a widely intended practice, with 72% of respondents considering its application in the future. Next, *CCF* was planned to be practiced by 64% of respondents. Nearly as many forest owners (57% of respondents) intended to implement *extended rotation periods*. The management method with the lowest intentions was *ash fertilization of peatlands*. Nevertheless, 37% of forest owners reported intending to use it in the future.

Responding forest owners generally expressed positive *attitudes* towards carbon sequestration, water protection, and biodiversity conservation. They prioritized water protection, with a strong majority (85%) completely or somewhat agreeing on

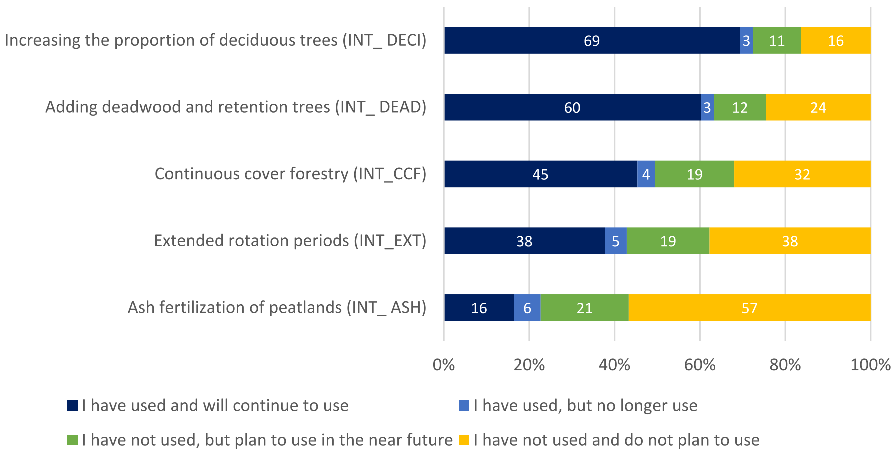


Fig. 2 Forest owners' intentions to implement different EFMPs (abbreviations are provided in Table 2)

its importance, but positive attitudes were also evident for biodiversity conservation (79% agreed) and carbon sequestration (71% agreed) (Fig. 3).

Regarding *subjective norms*, more than half of the respondents indicated that forest biodiversity (58%) and water protection (55%) were expected of them by people who are important to them. A slightly smaller share of respondents (43%) agreed that their referents expected them to enhance carbon sequestration.

Concerning *perceived behavioral control*, the majority of respondents believed they could enhance all three goals in their forest management. However, they felt most confident about increasing biodiversity: 67% of respondents agreed they could effectively manage their forests to achieve this goal.

Regarding *beliefs about the impacts* of the different practices, CCF and extending rotation periods were believed to have the greatest impact on carbon sequestration, with 40% and 41% of respondents believing that these practices would enhance or improve carbon sequestration to a significant or moderate extent, respectively (Fig. 4).

CCF was also believed to have the greatest impact on water protection, with 44% of respondents believing that it would enhance or improve water protection. Nearly a third of respondents also believed that extending rotation periods would have a significant or moderate impact on water protection. In contrast, only 8% of respondents viewed ash fertilization of peatlands as a significant or moderately effective practice for improving water protection.

Regarding biodiversity, beliefs about the outcomes of the practices were more evenly distributed. CCF, adding dead wood and retention trees, and increasing the proportion of deciduous trees were seen as practices that over 50% of respondents believed would enhance or improve biodiversity to a significant or moderate extent. Extending rotation periods was also believed to have an average impact (45% of respondents).

Factors Affecting Forest Owners' Intentions to Implement EFMPs: SEM Results

Descriptive statistics for the variables utilized in the SEMs are presented in Table 2. The structural equation model (Model 1) for the relationships between the intention (INT) to implement five EFMPs and the factors for attitude (F_ATT), subjective norms (F_SN), and perceived behavioral control (F_PBC) is presented in Fig. 5. All the parameters differed from zero ($p < 0.05$), except for two regression coefficients with dashed lines. Based on the model fit indices, the overall model fit was acceptable (CFI > 0.90 and SRMR < 0.08), although the RMSEA value is only slightly above the recommended threshold of 0.08.

As hypothesized, forest owners' attitudes towards CS, WP, and BC had a significant positive influence on the intention to use EFMPs ($\beta = 0.341$, $p < 0.05$). The factors SN and PBC did not have statistically significant effects on the intention ($\beta = 0.073$, $p = 0.65$ and $\beta = 0.041$, $p = 0.74$). The model explained 16.4% of the total variation in intention. Among the environmental objectives underlying the factors (ATT, SN, PBC), WP and BC in particular had high loadings. In all the factors, CS had lower importance. Notably, when ATT factor was removed from the model, SN

Table 2 Descriptive statistics for the variables (N = 58–101)

Variable name	Survey measure	N	Mean	Std Dev	Model
	INTENTION TO IMPLEMENT EFMPs: How much experience do you have with the methods?				M1
INT	Intention to implement five EFMPs	101	3.01	1.45	M1
INT(2)	Intention to implement two EFMPs (INT_EXT, INT_CCF)	99	1.19[a]	0.85	M2
INT_ DECI	Increasing the proportion of deciduous trees	98	0.81[b]	0.40	M1
INT_ ASH	Ash fertilization of peatlands	97	0.37[b]	0.49	M1
INT_EXT	Extended rotation period	98	0.57[b]	0.50	M1, M2
INT_CCF	Continuous cover forestry	97	0.64[b]	0.48	M1, M2
INT_ DEAD	Adding deadwood and retention trees	98	0.72[b]	0.45	M1
F_ATT	ATTITUDE: What is your opinion of the following objectives regarding forestry management on your property?				M1
ATT_CS	Carbon sequestration	97	3.86	1.13	M1
ATT_WP	Water protection	98	4.30	0.97	M1, M2
ATT_BC	Biodiversity conservation	98	4.02	0.99	M1
F_SN	SUBJECTIVE NORMS: Are you in agreement or disagreement with the following statements?				M1
SN_CS	The people important to me in forestry matters believe that I should enhance carbon sequestration	95	3.25	1.02	M1, M2
SN_WP	The people important to me in forestry matters believe that I should enhance water protection	95	3.54	1.08	M1
SN_BC	The people important to me in forestry matters believe that I should enhance biodiversity conservation	94	3.62	1.07	M1, M2
F_PBC	PERCEIVED BEHAVIORAL CONTROL: Are you in agreement or disagreement with the following statements?				M1
PBC_CS	I believe that I could enhance the carbon sequestration of my forests	96	3.55	1.06	M1
PBC_WP	I believe I could enhance the water protection of my forests	97	3.47	1.08	M1
PBC_BC	I believe I could increase the biodiversity of my forests	97	3.65	1.01	M1
F_BB_CS	BEHAVIORAL BELIEFS (CARBON SEQUESTRATION): To what extent do you assess that the following forestry practices enhance or sustain carbon sequestration in forests?				IM
BB_CS_ DECI	Increasing the proportion of deciduous trees	81	3.01	1.05	IM

Table 2 (continued)

Variable name	Survey measure	N	Mean	Std Dev	Model
BB_ CS_ ASH	Ash fertilization of peatlands	66	3.24	1.22	IM
BB_ CS_ EXT	Extended rotation period	82	3.27	1.18	M2
BB_ CS_CC	Continuous cover forestry	91	3.12	1.36	M2
BB_ CS_ DEAD	Adding deadwood and retention trees	83	2.34	1.40	IM
F_BB_WP	BEHAVIORAL BELIEFS (WATER PROTECTION): To what extent do you assess that the following forestry practices enhance or sustain water protection of forests?				M2
BB_WP_ DECI	Increasing the proportion of deciduous trees	82	2.71	1.21	IM
BB_ WP_ ASH	Ash fertilization of peatlands	58	2.26	1.10	IM
BB_ WP_ EXT	Extended rotation period	79	3.16	1.10	M2
BB_ WP_CC	Continuous cover forestry	87	3.31	1.32	M2
BB_ WP_ DEAD	Adding deadwood and retention trees	80	2.23	1.33	IM
F_BB_BC	BEHAVIORAL BELIEFS (BIODIVERSITY CONSERVATION): To what extent do you assess that the following forestry practices enhance or sustain biodiversity conservation in forests?				M2
BB_BC_ DECI	Increasing the proportion of deciduous trees	90	3.73	1.14	IM
BB_ BC_ ASH	Ash fertilization of peatlands	67	2.42	1.22	IM
BB_ BC_ EXT	Extended rotation period	88	3.51	1.18	M2
BB_ BC_CC	Continuous cover forestry	90	3.69	1.23	M2
BB_ BC_ DEAD	Adding deadwood and retention trees	90	3.51	1.43	IM

Ranges of means: [a](0–2), [b](0–1), and all other variables (1–5)

M1 = Model 1, M2 = Model 2, IM = In the initial model 2 but not in the final model 2 *(Model 2)*

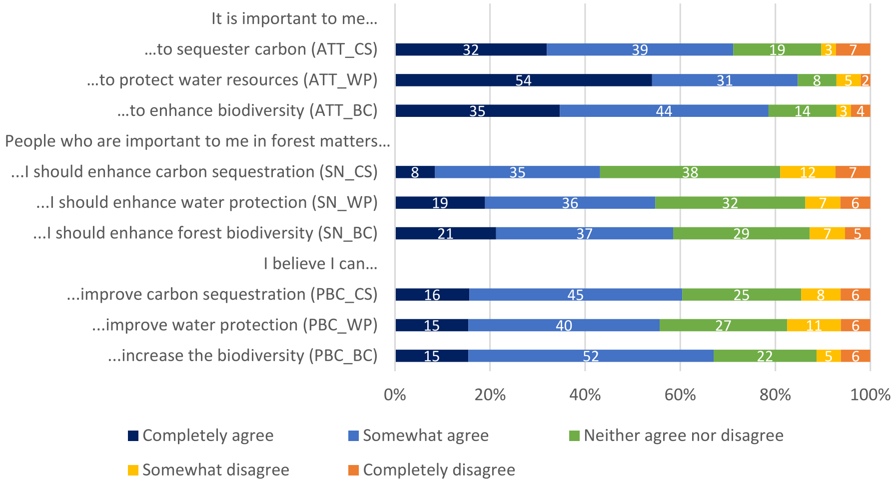


Fig. 3 Forest owners' attitudes (ATT), subjective norms (SN), and perceived behavioral control (PBC) regarding carbon sequestration (CS), water protection (WP), and biodiversity conservation (BC) in forest management (abbreviations for measures are provided in Table 2)

Fig. 4 Forest owners' beliefs regarding the outcomes of EFMPs for carbon sequestration (CS) in the top section, water protection (WP) in the middle section, and biodiversity conservation (BC) in the bottom section (abbreviations for measures are provided in Table 2)

became significant, indicating their independent contribution to intention ($\beta = 0.318$, $p = 0.007$). The inclusion of three control variables slightly increased the effect of ATT on intention ($\beta = 0.438$, $p = 0.002$). Gender and use of paid forest advisory

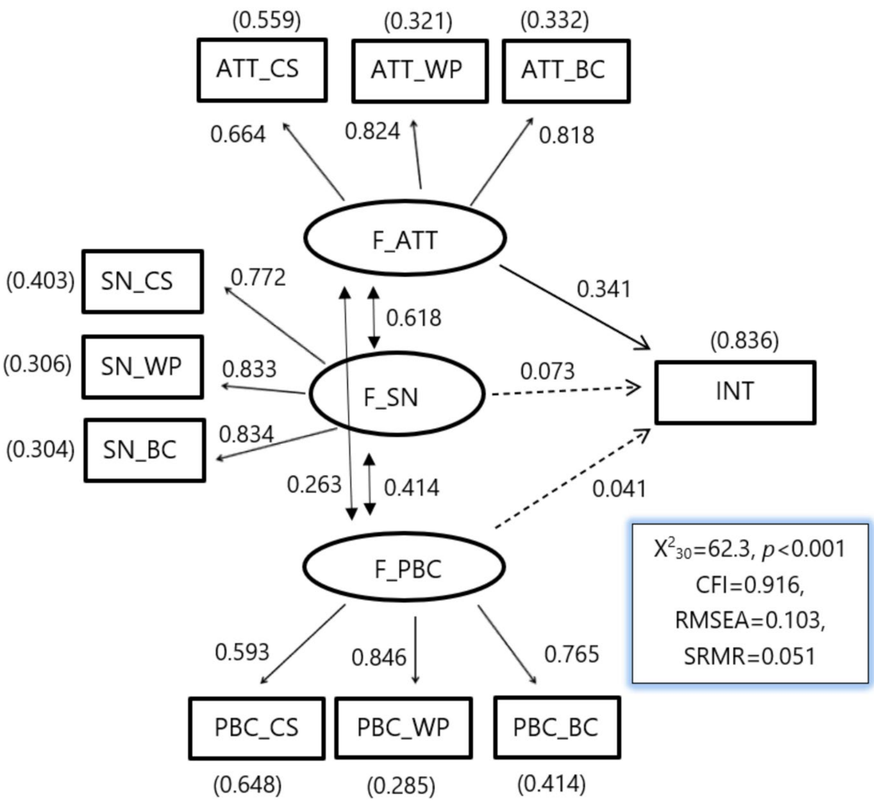


Fig. 5 Structural equation model for the relationships between the intention (INT) and the factors attitude (ATT), subjective norms (SN) and perceived behavioral control (PBC). CS stands for carbon sequestration, WP for water protection, and BC for biodiversity conservation. Values are standardized and the paths with dashed lines are not statistically significant. Error variances reflect the proportion of variance not accounted for by the model. Abbreviations for measures are provided in Table 2. N = 102. (*Model 1*)

services had statistically significant effects on intention ($\beta = -0.290$, $p = 0.002$ and $\beta = 0.265$, $p = 0.003$, respectively), while the effect of forest ownership size was not significant ($\beta = -0.104$, $p = 0.261$).

Model 2 was employed to explore the potential influence of beliefs on the impacts of EFMPs (the initial model in Fig. 1). Here, we specifically examined the impacts of latent beliefs regarding the effectiveness of EFMPs on the observed variables: attitude, subjective norms, and perceived behavioral control. It was then assessed how these beliefs, via ATT, SN, and PBC, ultimately influence the intention to implement these practices.

In the initial model, all five EFMPs ("Appendix 2") were included in beliefs regarding the outcomes as well as in the intention. However, the beliefs related to *ash fertilization of peatlands* did not contribute to the factor of beliefs. Furthermore, *increasing the proportion of deciduous trees* had a weak loading. Leaving out the intention and related beliefs concerning *adding deadwood and retention trees* considerably improved the model fit. To limit the final model to the intention to implement two EFMPs, *extended rotation* and *CCF,* we constructed a new intention variable, INT(2), obtaining values from zero to two (Table 2). Limiting the model to these two EFMPs was supported by our sample size, the significant associations between model variables, and the improved model fit. While the overall model fit of the initial Model 2 (presented in "Appendix 2") was poor, the improved model had an acceptable model fit based on indices (Fig. 6).

From the ATT, SN, and PBC related to three environmental objectives, only those with a significant association either with beliefs or intention were included. Therefore, from the nine variables (three objectives for each of the three concepts), only two were included in the final model. Connections from the behavioral belief factors for water protection (BB_WP) and biodiversity conservation (BB_BC) to the observed variables, ATT_WP and SN_BC, both presented strong associations ($p<0.001$). Thus, while the beliefs factor related to biodiversity conservation (BB_BC) explained the subjective norms (SN_BC), the factor of behavioral beliefs regarding water protection explained the attitude towards water protection (ATT_WP). Moreover, the attitude towards water protection (ATT_WP) and subjective norms of biodiversity conservation (SN_BC) also explained the intention to implement EFMPs ($\beta=0.356$, $p<0.001$ and $\beta=0.219$, $p=0.021$, respectively). The model explained 20% of the total variation in the intention to implement the two EFMPs.

Discussion and Conclusions

This study aimed at filling the gap in understanding the intentions of private forest owners to implement various EFMPs. Previous research on boreal forests has largely overlooked the relationship between multiple environmental objectives and the adoption of diverse EFMPs (e.g. Juutinen et al. 2020). Here, we brought environmental objectives into the application of TPB to the implementation of various forest management practices by private forest owners.

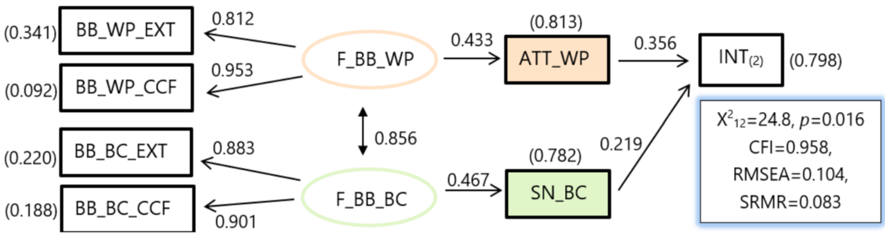


Fig. 6 The structural equation model showing the associations between beliefs regarding the impacts of extended rotation (EXT) and continuous cover forestry (CCF) on attitude towards water protection (ATT_WP) and subjective norms for biodiversity conservation (SN_BC) and further to the intention to implement the two practices INT(2). The model coefficients are statistically significant standardized estimates. Error variances reflect the proportion of variance not accounted for by the model. All variables are described in more detail in Table 2. N = 102. *(Model 2)*

Our findings reveal that forest owners in the case area hold generally evident intentions to implement EFMPs (Fig. 2). However, we could only partially explain the intention to implement EFMPs with the variables arising from TPB. In the first estimated SEM model, we found ATT towards environmental objectives to have the strongest positive impact, while SN and PBC did not significantly associate with the intention to implement EFMPs (Fig. 5). Our results are in line with Karppinen (2005), who found that attitudes, but also past behavior, most strongly affected the selection of reforestation method. However, in the aforementioned study, the subjective norm and perceived behavioral control factors also had a smaller but still significant influence on the intention. Interestingly, in our case, a strong reciprocal relationship emerged between attitudes and subjective norms, suggesting that forest owners with a positive attitude towards environmental objectives may influence the perceptions of others (important people in their network), leading to a stronger subjective norm that, in turn, reinforces the positive attitude.

However, we cannot fully compare our results with previous studies of explaining intention to implement EFMPs, as our ATT, SN, and PBC focused on environmental objectives and not directly on implementing the behavior in question. Nevertheless, we can conclude that our approach, integrating environmental objectives in explaining the implementation of management practices, produced interesting but less self-evident results than the conventional way of applying TPB. In the conventional TPB approach, the attitude towards a behavior (e.g., a positive perception of the behavior) is also conceptually quite closely linked to the intention to perform that behavior in the future (Ajzen 1991; Sheeran 2002).

Previous studies on forest owner objectives have classified forest owners and analyzed the differences in their management choices between these classes (e.g., Kuuluvainen et al. 1996; Finley and Kittridge 2006; Ní Dhubháin et al. 2007; Blanco et al. 2015). In these studies, the variety of objectives extends beyond the environmental focus of this study. Compared to these studies, TPB introduces more detailed theoretical constructs and assumptions about the associations between variables. Although we were able to integrate environmental objectives into a TPB-based approach, more theoretical work, such as deep interview data, is needed to understand how wide variety of objectives are linked to the beliefs and attitudes of forest owners (Häyrinen et al. 2025). Other approach worth further testing would be building separate TPB-based models for different objective classes.

Owners' beliefs regarding the impact of different EFMPs varied, and they generally believed that EFMPs have a greater impact on biodiversity conservation than on promoting carbon sequestration or water protection (Fig. 4). Furthermore, the high proportion of "I can't say" responses for ash fertilization suggests its relative unfamiliarity among forest owners. While ash fertilization has been shown to enhance tree growth in drained peatlands (Haveraaen 2019), forest owners did not generally believe that it would benefit water protection. This highlights the need to increase forest owners' awareness of the environmental benefits of ash fertilization, as it is a promising method to minimize the need for ditch restoration in peatlands and consequently reduce the effects of drainage on water bodies.

In the second SEM model, the findings revealed that, among the five EFMPs, the intentions to implement extended rotation and CCF were the most easily predicted.

These intentions were significantly associated with the attitude towards water protection, subjective norms for biodiversity conservation, and related beliefs (Fig. 6). This result can be aligned with the results of Koskela and Karppinen (2024), who indicated that behavioral beliefs had an effect on safeguarding biodiversity, in which the positive impact on the climate and waterbodies was one of the most important factors in the outcome evaluations. The lack of statistical significance in forest owners' beliefs about the impact of practices on carbon sequestration in Model 2 can probably be explained by the perception of carbon sequestration as an abstract concept. Forest owners may find it more challenging to observe the effects of forest management practices on carbon sequestration, particularly in the short term, compared to promoting biodiversity (see e.g. Karppinen et al. 2018). Another explanation can be found from free riding (e.g. Frings et al. 2023), where forest owners may perceive that the benefits of carbon sequestration are shared broadly, reducing their individual incentive to prioritize or invest in it, especially if societal pressure is low. These competing explanations warrant further research in the future.

The limited number of responses (n = 102) restricted the application of the data, preventing us from testing the effects of sociodemographic variables using subgroups within SEM framework. However, we included background variables (gender, use of forest advisory services and the amount of forest owned) as control variables in alternative Model 1. Contrary to previous studies (Juutinen et al. 2020; Husa and Kosenius 2021) our analysis revealed that men significantly exhibited a higher intention to act. Moreover, those who had used advisory services also showed a higher intention. Although, comprehensive analysis of background variables was not possible due to the small sample size and remains a topic for further studies.

Furthermore, the data were gathered as part of a larger survey, restricting the number of measures we could incorporate in the questionnaire. While the characteristics of study respondents were generally aligned with past research on Finnish forest owners, the response rate of 20% means that generalizing these findings to the entire forest owner population requires significant caution. Additionally, the study's focus on a specific region limits the generalizability of its results to other geographical or societal contexts. Despite these weaknesses, we were able to provide detailed insights on forest owners' intentions in the case area.

A surprisingly high number of respondents reported practicing CCF (Fig. 2). This could be because the 2014 Forest Act revision legalized CCF, and the definition and practices of CCF might still be vague among forest owners, leading to some confusion. While current data on uneven-aged management practices in Finland is limited, projections suggest it will increase to 19% of private forest land (Juutinen et al. 2020). It is also possible that some respondents in our sample were already experimenting with CCF, which would not yet have been reflected in official statistics. While the previous literature has revealed a correlation between intention and behavior (e.g. Sheeran 2002), we did not have an opportunity to follow the actual behavior of forest owners. Given the importance of CCF for water protection and carbon balance, more research on owners knowledge and interest in implementing it in the future is needed.

From a policy perspective, understanding how to promote EFMPs remains crucial. The results of this study suggest that influencing forest owners' attitudes by offering evidence-based information is particularly essential. Looking towards the future, the growing demand for various ecosystem services necessitates the promotion of multi-objective forest management by society (Díaz-Yáñez et al. 2021). This approach aligns with the findings of Juutinen et al. (2020), who indicated that forest owners in Finland generally plan to implement various management regimes in their forest holdings. However, in order to more effectively promote different management practices among private forest owners, the development of well-designed monetary incentives is needed, especially for carbon sequestration. The effectiveness of these incentives in influencing forest owners' behavior warrants further research.

Moreover, some previous studies have highlighted the pivotal role that trusted forest professionals play in the decision-making processes of many Finnish forest owners (e.g. Hujala et al. 2009; Laakkonen et al. 2018). Similarly, the findings of Koskela and Karppinen (2024) indicate that forestry professionals and other forest owners play significant roles as sources of normative pressure. This underscores the need for timely information and training for forest advisors.

This article suggested several avenues for future research. To advance our understanding of private forest owners' intentions to implement diverse EFMPs, future research should also consider employing longitudinal studies that capture changes in attitudes, subjective norms, and perceived behavioral control over time (Karppinen et al. 2020). This approach would allow researchers to assess how these factors evolve in response to new information and policy changes. Following the change in attitudes and intentions regarding carbon sequestration in particular was demonstrated to be important based on our analysis. Additionally, a similar approach could be used to compare reported intentions with actual behaviors, allowing for a better understanding of the link between intentions and practices. Furthermore, it could also be applied to several EFMPs in other forestry-rich countries to explore broader applicability.

Appendix 1

The lower triangle consists of Pearson's correlation coefficients for the sum variable of intention (INT) and the variables of attitude (ATT), subjective norms (SN), perceived behavior control (PBC), and behavioral beliefs (BB). *P*-values are presented in the upper triangle. N = 54–102.

	INT	INT_34	ATT_CS	ATT_WP	ATT_BC	SN_CS	SN_WP	SN_BC	PBC_CS	PBC_WP	PBC_BC	BB_CS_ DECI	BB_CS_ ASH
INT	1	0.000	0.103	0.000	0.002	0.110	0.023	0.002	0.103	0.312	0.194	0.976	0.287
INT_34	0.740	1	0.016	0.000	0.001	0.037	0.035	0.002	0.140	0.011	0.0212	0.282	0.549
ATT_CS	0.167	0.246	1	0.000	0.000	0.000	0.002	0.002	0.161	0.455	0.613	0.146	0.292
ATT_WP	0.368	0.421	0.554	1	0.000	0.000	0.000	0.004	0.159	0.008	0.049	0.574	0.097
ATT_BC	0.310	0.326	0.539	0.670	1	0.001	0.000	0.000	0.638	0.156	0.138	0.035	0.357
SN_CS	0.166	0.216	0.509	0.380	0.340	1	0.000	0.000	0.002	0.020	0.093	0.217	0.850
SN_WP	0.234	0.218	0.311	0.466	0.426	0.638	1	0.000	0.131	0.003	0.024	0.496	0.536
SN_BC	0.312	0.320	0.317	0.295	0.480	0.647	0.690	1	0.043	0.009	0.004	0.515	0.699
PBC_CS	0.168	0.152	0.144	0.145	0.049	0.309	0.156	0.210	1	0.000	0.000	0.516	0.648
PBC_WP	0.104	0.257	0.077	0.266	0.145	0.238	0.299	0.268	0.498	1	0.000	0.943	0.846
PBC_BC	0.134	0.235	0.052	0.200	0.152	0.174	0.232	0.292	0.450	0.649	1	0.471	0.210
BB_CS_ DECI	−0.003	0.123	0.167	0.065	0.239	0.144	0.080	0.077	0.076	−0.008	0.083	1	0.218
BB_CS_ASH	0.133	0.075	0.133	0.206	0.115	0.024	0.079	0.050	−0.058	−0.025	−0.158	0.161	1
BB_CS_EXT	0.083	0.295	0.138	0.317	0.308	0.361	0.435	0.404	0.136	0.240	0.124	0.337	0.265
BB_CS_CC	0.281	0.480	0.384	0.417	0.506	0.433	0.414	0.497	0.154	0.307	0.175	0.287	−0.027
BB_CS_ DEAD	0.091	0.146	0.216	0.251	0.416	0.252	0.346	0.422	0.119	0.230	0.063	0.197	−0.030
BB_WP_ DECI	0.090	0.244	0.147	0.262	0.223	0.219	0.087	0.060	−0.023	0.113	0.187	0.509	0.035
BB_WP_ ASH	0.173	0.103	0.030	0.230	0.051	0.079	0.046	0.031	−0.012	0.092	−0.068	−0.006	0.291
BB_WP_ EXT	0.193	0.359	0.359	0.470	0.410	0.330	0.382	0.302	0.127	0.196	0.135	0.183	0.167
BB_WP_CC	0.418	0.511	0.303	0.380	0.442	0.359	0.355	0.392	0.199	0.249	0.180	0.198	0.239

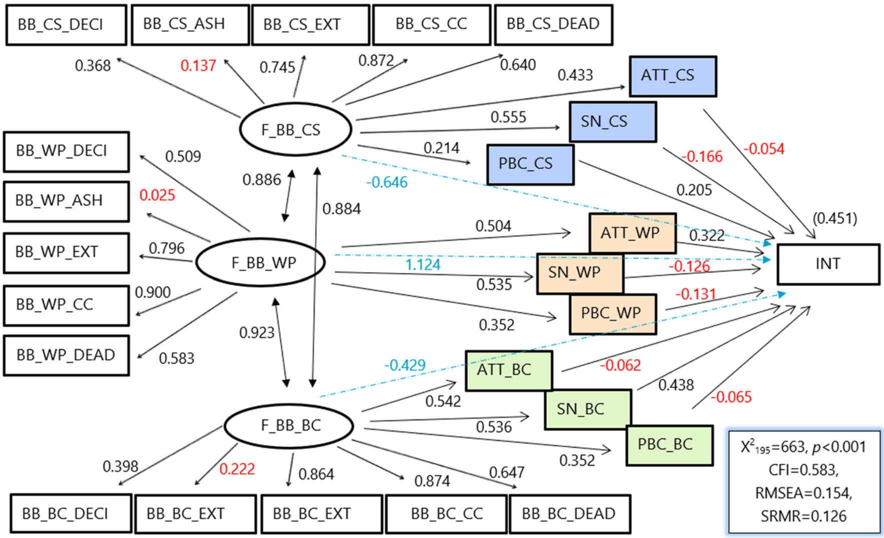
	INT	INT_34	ATT_CS	ATT_WP	ATT_BC	SN_CS	SN_WP	SN_BC	PBC_CS	PBC_WP	PBC_BC	BB_CS_ DECI	BB_CS_ ASH
BB_WP_ DEAD	0.143	0.241	0.128	0.336	0.338	0.199	0.341	0.372	0.093	0.339	0.237	0.174	−0.089
BB_BC_ DECI	0.220	0.137	0.031	0.115	0.191	−0.004	0.117	0.031	0.055	0.120	0.179	0.382	0.240
BB_BC_ ASH	0.332	0.235	0.167	0.298	0.286	0.209	0.066	0.135	−0.099	−0.022	−0.173	0.121	0.264
BB_BC_ EXT	0.255	0.355	0.326	0.312	0.369	0.437	0.434	0.450	0.246	0.198	0.087	0.409	0.318
BB_BC_CC	0.278	0.430	0.452	0.378	0.344	0.456	0.454	0.436	0.217	0.262	0.212	0.303	0.154
BB_BC_ DEAD	0.182	0.148	0.282	0.325	0.379	0.168	0.417	0.343	0.199	0.246	0.182	0.179	0.259

	BB_CS_ EXT	BB_CS_CC	BB_CS_ DEAD	BB_WP_ DECI	BB_WP_ ASH	BB_WP_ EXT	BB_ WP_CC	BB_ WP_ DEAD	BB_BC_ DECI	BB_BC_ ASH	BB_BC_ EXT	BB_BC_ CC	BB_BC_ DEAD
INT	0.459	0.007	0.414	0.422	0.195	0.088	0.000	0.210	0.037	0.006	0.016	0.008	0.088
INT_34	0.007	0.000	0.191	0.031	0.443	0.001	0.000	0.032	0.205	0.056	0.001	0.000	0.167
ATT_CS	0.222	0.000	0.053	0.195	0.823	0.001	0.005	0.261	0.773	0.178	0.002	0.000	0.007
ATT_WP	0.004	0.000	0.023	0.019	0.083	0.000	0.000	0.003	0.288	0.014	0.003	0.000	0.002
ATT_BC	0.005	0.000	0.000	0.047	0.706	0.000	0.000	0.002	0.074	0.019	0.000	0.001	0.000
SN_CS	0.001	0.000	0.025	0.056	0.564	0.004	0.001	0.083	0.974	0.095	0.000	0.000	0.120
SN_WP	0.000	0.000	0.002	0.452	0.735	0.001	0.001	0.002	0.282	0.601	0.000	0.000	0.000
SN_BC	0.000	0.000	0.000	0.605	0.822	0.009	0.000	0.001	0.776	0.285	0.000	0.000	0.001
PBC_CS	0.231	0.153	0.294	0.842	0.928	0.274	0.070	0.417	0.614	0.430	0.023	0.044	0.063
PBC_WP	0.032	0.004	0.039	0.323	0.498	0.088	0.022	0.002	0.270	0.862	0.067	0.014	0.021
PBC_BC	0.272	0.101	0.575	0.098	0.614	0.241	0.098	0.037	0.098	0.164	0.424	0.047	0.090

	BB_CS_EXT	BB_CS_CC	BB_CS_DEAD	BB_WP_DECI	BB_WP_ASH	BB_WP_EXT	BB_WP_CC	BB_WP_DEAD	BB_BC_DECI	BB_BC_ASH	BB_BC_EXT	BB_BC_CC	BB_BC_DEAD
BB_CS_DECI	0.004	0.012	0.095	0.000	0.967	0.138	0.091	0.150	0.001	0.366	0.000	0.009	0.127
BB_CS_ASH	0.036	0.828	0.815	0.789	0.033	0.211	0.061	0.497	0.056	0.045	0.010	0.228	0.042
BB_CS_EXT	1	0.000	0.000	0.010	0.674	0.000	0.000	0.001	0.054	0.375	0.000	0.000	0.000
BB_CS_CC	0.666	1	0.000	0.000	0.232	0.000	0.000	0.000	0.144	0.140	0.000	0.000	0.002
BB_CS_DEAD	0.533	0.625	1	0.082	0.902	0.002	0.001	0.000	0.346	0.074	0.001	0.002	0.000
BB_WP_DECI	0.301	0.396	0.203	1	0.061	0.000	0.000	0.000	0.000	0.001	0.003	0.002	0.395
BB_WP_ASH	−0.059	−0.162	−0.017	0.252	1	0.679	0.858	0.104	0.923	0.000	0.636	0.653	0.489
BB_WP_EXT	0.539	0.611	0.360	0.485	−0.058	1	0.000	0.000	0.001	0.050	0.000	0.000	0.000
BB_WP_CC	0.563	0.740	0.368	0.426	−0.024	0.778	1	0.000	0.000	0.208	0.000	0.000	0.000
BB_WP_DEAD	0.382	0.456	0.716	0.548	0.218	0.484	0.479	1	0.042	0.089	0.000	0.001	0.000
BB_BC_DECI	0.220	0.161	0.109	0.576	0.013	0.361	0.428	0.234	1	0.044	0.000	0.005	0.001
BB_BC_ASH	0.117	0.185	0.223	0.414	0.551	0.255	0.161	0.218	0.251	1	0.040	0.605	0.908
BB_BC_EXT	0.656	0.624	0.358	0.338	0.064	0.587	0.726	0.395	0.377	0.251	1	0.000	0.000
BB_BC_CC	0.552	0.712	0.344	0.347	−0.062	0.622	0.737	0.378	0.302	0.065	0.798	1	0.000
BB_BC_DEAD	0.479	0.335	0.441	0.099	−0.095	0.466	0.451	0.455	0.366	−0.015	0.576	0.562	1

Appendix 2

The initial Model 2 illustrating the relationships between observed variables (rectangles) and latent constructs (ellipses). Single-headed arrows represent standardized regression coefficients and factor loadings. Statistically non-significant paths are colored in red. The dashed arrows from the factors to the intention highlight paths that were found to be problematic. Double-headed arrows show correlations between the factors. The model fit indices in the box indicate a poor model fit.



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Declarations

Conflict of interest The authors declare no conflicts of interest.

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