

Finnish forest owners' willingness to participate in result-based carbon offset schemes.

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ABSTRACT

Forests are vital carbon sinks, playing a key role in combating climate change by absorbing nearly one-third of global annual greenhouse gas emissions. In Finland, forests cover 75 % of the country's land area. However, there is currently no policy in place to encourage increased carbon sequestration on privately-owned forestland. This study aims to explore forest owners' preferences for results-based carbon offset schemes and their attributes, contributing to the debate on whether to compensate forest owners based on carbon sequestration. To achieve this, data on forest owners' preferences for alternative carbon offset schemes were collected through an online survey, and a choice experiment was conducted. The results revealed significant diversity among Finnish forest owners in their attitudes towards carbon offset schemes. However, compensatory carbon payments appeared to be the only attribute that would motivate respondents in all classes to participate in carbon schemes. The results of both the conditional logit (CL) model and the latent class model (LC) indicated a high preference among forest owners for the non-participation option, suggesting low willingness to accept new schemes.

1. Introduction

Forests are essential for human well-being through the production of wood and non-wood products, the replenishment and purification of water supplies, and the provision of social benefits, including opportunities for recreational activities (Brockerhoff et al., 2017). Forests are carbon sinks and are therefore crucial in preventing climate change (CC), because they remove carbon from the atmosphere. The global forest sink is equivalent to almost half of fossil-fuel emissions ($7.8 \pm 0.4 \text{ Pg Cyr}^{-1}$ in 1990–2019), but due to tropical deforestation ($2.2 \pm 0.5 \text{ Pg Cyr}^{-1}$ in 1990–2019), two-thirds of the benefit from the sink has been negated (Pan et al., 2024). Since the 1990s, climate policy has increasingly focused on the role of forests in mitigating climate change, becoming a prominent area of research. The capacity of forests to sequester carbon dioxide is recognized as pivotal in reducing global warming. Carbon sequestration is increasingly portrayed as a cost-effective method for addressing CC (UNFCCC, 1998). Certain silvicultural practices such as thinning, which is commonly used to improve timber quality and increase economic benefits during a forestry rotation period (Ogden and Innes, 2009), have the potential to increase carbon sequestration (Canadell and Raupach, 2008; Griscom et al., 2017).

Furthermore, forest management practices such as moderate harvesting intensities, long rotations and fertilization could be used to increase carbon storage (Ameray et al., 2021).

Globally, forest ecosystems are also significantly affected by CC, changing the availability of products and services. Higher temperatures and changing precipitation regimes impact growth and production (Ma et al., 2019). Similarly, the rise in the frequency and severity of natural disasters points to significant declines in the value of forests in the years to come (Hanewinkel et al., 2013). This risk has been realized, particularly in Germany, where recent forest damage has heavily reduced the volume and area of Norway spruce forests and the total growth of forests (Bundeswaldinventur, 2024).

In Finland, there is extensive coverage with forestry land, spanning over 86 % of the land area. However, due to unproductive and poorly productive lands, productive forests account for 75 % of the land area (Korhonen et al., 2024). According to the latest National Forest Inventory (NFI), out of the 26.2 million hectares of forestry land, 51 % is under ownership by private individuals (family forests). Furthermore, annual forest growth in Finland amounts to approximately 103 million m^3 , whereas roundwood removal ranges between 70 and 75 million m^3 and the total drain between 85 and 90 million m^3 annually (OFS, 2024).

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Finland is the sixth-largest holder of timber resources in Europe, following Russia, Sweden, Germany, France and Poland (FAO, 2020).

The Finnish Government has committed to achieving carbon neutrality by 2035. The Climate Change Act, enacted in 2022, sets emission reduction goals for 2030, 2040 and 2050 and establishes the 2035 carbon neutrality target. Under EU regulations, Finland is required to reduce greenhouse gas emissions in the effort-sharing sector (non-Emission Trading Scheme (ETS) sectors) by half by 2030 compared to 2005 levels and ensure that the land-use sector remains a net carbon sink (Huttunen et al., 2024).

Currently, the EU is preparing legislative proposals on soil health and carbon removal certification, with a key objective of supporting CC mitigation and adaptation in the land use sector. The aim is to create certified carbon removals that can be monetized through private initiatives and public sector support, as well as generating commercial benefits from environmentally conscious consumers (EC, 2024). While Finland recognizes the importance of forests in its carbon neutrality goals, there is currently no policy mechanism in place to encourage increased carbon sequestration and storage on private forestland in the country (Assmuth et al., 2024). However, there is active discussion in Finland about implementing economic incentives for forest owners to maintain and enhance carbon sinks. The government's updated Integrated National Energy and Climate Plan outlines national targets and policy measures to achieve the EU's energy and climate goals for 2030, emphasizing the importance of carbon sinks in meeting these objectives (Ministry of Economic Affairs and Employment of Finland, 2024).

The discussion on carbon policies has focused on voluntary carbon schemes, as they have been seen as acceptable and also politically more easily approvable than other types of policy tools. As the willingness of forest owners to enrol is a crucial condition for a successful voluntary carbon scheme, it is important to design programmes that would be feasible and attractive to a large proportion of forest owners. In earlier studies, the proportion of forest owners interested in participation has varied substantially, depending on the features of the schemes (i.e., Håbesland et al., 2016; Markowski-Lindsay et al., 2011; Khanal et al., 2017). The rather low interest of the forest owners calls for an analysis of the factors in scheme design that could enhance or hinder participation in the schemes.

In results-based carbon schemes, farmers or forest owners receive compensation based on the actual results they achieve in carbon mitigation, either through capturing carbon or reducing emissions (Davide, 2021). Results-based payments include stringent monitoring and can be implemented through auctions, carbon credits, product labels or certificates (McDonald, Hugh et al., 2021). Currently, increased budgetary constraints also call for better cost-effectiveness, which may be achieved with results-based approaches (Burton and Schwarz, 2013). However, action-based payments, which are the most common approach, are simpler, with lower monitoring requirements for landowners, and can be paid upfront or after contract implementation (Raina et al., 2024). In action-based payments, participants receive payments for taking specific carbon-related actions (e.g., payments for extended rotations in forest plantations (West et al., 2019)) and are granted regardless of actual results.

2. Background

A small number of studies have examined the factors that influence forest owners' willingness to participate in carbon offset programmes (Håbesland et al., 2016) within a European context. However, most of the literature focuses on the United States (Dickinson et al., 2012; Markowski-Lindsay et al., 2011; Miller et al., 2012; Khanal et al., 2017; Sass et al., 2022) and Canada (White et al., 2018). The findings from past studies have been quite consistent and at times contradictory in relation to whether certain socio-economic characteristics have a positive, negative or no effect on participation in a carbon sequestration programme.

Most of these studies have surveyed forest owners regarding their willingness to enrol in potential carbon sequestration programmes or carbon trading programmes with different attributes. One of the most frequently included attributes is the **expected payment**. The majority of the studies have revealed a statistically significant preference among participants for programmes offering greater expected payments (Dickinson et al., 2012; Håbesland et al., 2016; Markowski-Lindsay et al., 2011; Miller et al., 2012; Soto et al., 2016; White et al., 2018). **Shorter time commitments** (Dickinson et al., 2012; Miller et al., 2012; White et al., 2018) as well as the **absence of a management plan requirement** have had a positive effect on programme participation in most studies (Dickinson et al., 2012; Håbesland et al., 2016; Khanal et al., 2017). Forest owners would be more willing to accept forest carbon sequestration programmes in the case of lower early **withdrawal penalties** (Dickinson et al., 2012; White et al., 2018).

The relationship between socio-economic characteristics and forest owners' willingness to participate in carbon sequestration programmes has also been investigated. Dickinson et al. (2012) and Markowski-Lindsay et al. (2011) determined that landowners with higher levels of **education** were more likely to participate in carbon sequestration programmes. Khanal et al. (2017) observed that **land size** and **income** were both positively and significantly associated with landowner participation behaviour. Landowners with a higher income and larger area of forestland would be more willing to delay harvest for increased carbon sequestration than lower income landowners with smaller land areas. However, **age** had a negative impact on willingness to participate, as relatively older landowners were less inclined to manage their forests for carbon sequestration (Khanal et al., 2017; Markowski-Lindsay et al., 2011). Several landowner characteristics have also been explored relative to carbon sequestration. The findings in the literature regarding the role of **gender** in participation have been contradictory. For example, Miller et al. (2012) and Alhassan et al. (2019) found that men were more likely to participate in carbon programmes, while Dickinson et al. (2012) observed that women were more likely to participate, and other studies have detected no significant gender effect (Markowski-Lindsay et al., 2011; Håbesland et al., 2016).

The impact of attitudinal variables on landowners' willingness to enrol in carbon schemes has also been tested in several studies. Landowners' **perceptions** that humans are contributing to CC (Håbesland et al., 2016) and that forestry can mitigate CC (Dickinson et al., 2012; Miller et al., 2012; Håbesland et al., 2016; Khanal et al., 2017) positively influenced the likelihood of participating in carbon sequestration programmes. In addition, Miller et al. (2012) demonstrated that the level of appreciation of the **non-market amenities** of their forest had a positive effect on participation. The **trust** in CC information from scientists or the government has shown a positive effect on forest owners' willingness to participate in a carbon programme, while legislative uncertainty in the carbon market was identified as a major barrier to participation (Alhassan et al., 2019).

A survey conducted in the US (Thompson and Hansen, 2012) examined respondents' views on the economic and environmental impacts of carbon sequestration and trading, alongside their land characteristics, land-use plans and demographics. According to the results, a larger land area and absentee ownership negatively influenced attitudes towards managing forests for carbon sequestration and trading, while plans to harvest, bequeath land to heirs, and higher educational levels positively affected these attitudes.

Forest owners face increasing risks from storm damage, pests and diseases, which impact forest management decisions (Blennow et al., 2014; Hanewinkel et al., 2013). Typically, damaged wood is removed for fuelwood or to reduce the risk of further damage, despite its potential as a significant carbon pool. Previous studies have examined how forest owners perceive and respond to these risks (Laakkonen et al., 2018; Venäläinen et al., 2020). However, two key aspects have remained unexplored: first, whether considering damaged wood in carbon compensation has an impact on forest owners' willingness to participate in

carbon offset schemes, and secondly, whether forest owners' intentions to mitigate damage in their own forest is connected to their willingness to enrol in carbon schemes.

The success of voluntary carbon programmes is dependent on the willingness of landowners to enrol in them, and knowledge of features that would increase the desirability of schemes is thus crucial for their development. This willingness to enrol can also be enhanced by a proactive approach, which refers to an emerging stream of research and practice. This approach differs significantly from traditional legal thinking and contract drafting, which focuses on the legal, safeguarding aspect of contracts to the detriment of other objectives (Haapio, 2013). A proactive approach takes better into account user-friendliness, flexibility, the mutual benefits for the contract parties and other factors that have been overlooked in the traditional approach. Therefore, it can enhance the willingness of forest owners to join a voluntary-based system, such as a carbon compensation scheme. The present study examined contract features, including incentives, flexibility and the user-friendliness of the programme, and how they affect forest owners.

Building upon past studies, this study seeks to extend understanding of the factors that affect the Finnish forest owners' willingness to participate in results-based carbon offset schemes in the Finnish context. While earlier investigations have laid a strong foundation by exploring carbon sequestration and carbon trade programmes, there has been limited research on forest owners' willingness to participate in results-based carbon schemes, which are not yet in place in Finland. In addition, forest owners' preferences regarding the inclusion of damaged wood left in or harvested from the forest in the additional growing stock for carbon compensation has not previously been examined in Finland or elsewhere in Europe, leaving a crucial gap in the literature. This study aims to fill this gap by conducting a survey and performing a choice experiment to identify potential heterogeneity among Finnish forest owner groups in their willingness to produce environmental benefits under a results-based policy. The aim of this paper is to answer the following research questions:

1. Is there heterogeneity in forest owners' preferences for the features of a results-based carbon offset scheme?
2. Which attributes and socio-economic factors influence forest owners' willingness to participate in results-based compensation schemes?
3. Do forest owners' attitudes towards climate change mitigation, risk and contract features differ among groups?
4. What are the estimated willingness-to-accept (WTA) compensation levels for forest owners to provide environmental benefits?

3. Materials and methods

3.1. Questionnaire-survey design

The materials for the study were collected via a structured quantitative survey with some qualitative open response options. The survey questions were designed to explore private forest owners' perspectives regarding 1) carbon sequestration and storage in their own forests and generally in Finland and 2) the policy measures and their acceptability to promote their societal goals. The general design of the survey questionnaire was based on earlier research on these topics (Leppänen and Hältia, 2023), interdisciplinary collaboration within the project consortium (expertise in forest ecology, economics, law and sociology), and stakeholder workshops organised in March and April 2022. Each workshop had 8–11 forest owner participants. The general purpose of the workshops was to gain an understanding of the forest owners' views regarding carbon sequestration and the protection of carbon stocks in forests generally, as well as whether they would consider participating in carbon schemes. The survey questionnaire was pretested with 9 forest owners who commented on the question clarity and understandability. Based on this pretesting, we clarified the wording of some difficult statements and improved the description of the carbon scheme.

In addition, the functioning of the survey questionnaire and especially the choice experiment part was tested in the soft launch process (described in section 3.3).

The final survey questionnaire consisted of four parts. The first part contained questions regarding the respondent's forest holding. The second part focused on forest owners' views on different management methods to increase the carbon storage and sequestration of forests, as well as previous forest damage, and the third part consisted of questions regarding policies and incentives to promote carbon storage and sequestration. The fourth part consisted of the choice experiment scenario, the choice tasks and questions about the desirability of the contract features. The last section comprised questions related to peatland forests for peatland owners, as well as questions on attitudes towards climate change mitigation and on the socio-economic background of the respondent.

Here, the aim is to examine certain programme characteristics and how they would increase the willingness of forest owners to enrol in a carbon compensation scheme. The design of the survey questionnaire considered factors commonly highlighted in the proactive approach, such as the incentivization, flexibility and user-friendliness of the contract. The survey assessed various aspects, including how easy it is to join the programme, the speed of the preparation and decision-making process, and the availability of advice in different stages of the scheme. It also considered the clarity of the terms and conditions, the opportunity for forest owners to decide on measures to increase carbon storage and whether withdrawal from the programme would require payments to be returned. Additionally, the survey examined the flexibility of the withdrawal option, the frequency of carbon offset payments (more than once every ten years), the initial level of compensation, whether compensation is based on the tree stock and whether compensation increases based on the results.

3.2. The discrete choice experiment

A discrete choice experiment (DCE) is a method pioneered by McFadden (1974), further developed by Louviere and Hensher (1983) and Louviere and Woodworth (1983) and is used to investigate individuals' preferences for market or non-market products. This approach combines the random utility theory (McFadden, 1974) and Lancaster's consumer theory (Lancaster, 1966), which states that consumers derive utility not directly from the product itself but from its individual attributes. Compared to other preferred methods, such as contingent valuation, DCE allows researchers to estimate trade-offs between different attributes rather than just capturing a single willingness-to-pay value (Hanley et al., 1998). DCE offers significant advantages by allowing the incorporation of novel items or features that may not currently exist in the real world and for which there is no existing data (Johnston et al., 2017). For example, in this study, forest owners were asked to choose among potential carbon offset schemes that are not currently in use in Finland.

The carbon scheme proposed to the survey respondents was designed to enhance the volume of the wood stock, i.e., growing stock and deadwood, of forest holdings relative to conventional forest management practices. This scheme encompasses the entire forest holding to avoid cherry-picking the most suitable sites for an increased carbon stock and the lowest opportunity costs (Badgley et al., 2022). Initially, the existing growing stock volume of the forest would be quantified, and a projected volume would be calculated based on a sequence of management actions derived from widely adopted forest management guidelines. Every ten years, the actual growing stock and deadwood volume would be measured and compared with the projected baseline. Carbon payments would be determined according to the volume exceeding this baseline. Forest owners retain the flexibility to select management strategies aimed at increasing the growing stock, with potential approaches including, for example, delaying thinning and harvesting operations or applying fertilization. In addition to

roundwood volume-based carbon payment, all forest owners who agree to the contract would receive an initial payment of 500 euros. This payment would need to be returned if the forest owner wanted to resign from the scheme during the first ten years. After that, the forest owner could continue in the scheme, but resigning was also possible without any withdrawal penalty.

The attributes for the carbon offset schemes and the levels of each attribute are listed in Table 1. The choice of the attributes is mainly based on the experiences from an earlier choice experiment application (Leppänen and Halltia, 2023), the literature and the forest owner workshops carried out for the project. The guiding principle in the scenario building and the attribute selection was to find attributes that could attract some forest owner groups, without compromising the main features of an effective carbon scheme (i.e., Assmuth et al., 2024). For example, regarding the first attribute (the initiator for the compensation arrangement), Horne (2006) demonstrated that private forest owners prefer themselves as the initiators of biodiversity conservation contracts over forest organizations, conservation trusts or environmental organizations. The source of financing for compensation payments is a relevant attribute when examining forest owners' preferences for the arrangements of carbon schemes. According to Assmuth et al. (2024), there are legal uncertainties and limitations related to a carbon compensation scheme within an EU member state. Both public funding and market-based funding have advantages and disadvantages, making it valuable to investigate whether forest owners have a strong preference for one over the other.

Considering deadwood in a carbon offset scheme is important, because it represents a critical carbon pool and unique biodiversity reservoir (Gao et al., 2015; Wijas et al., 2024). In managed forests, the volume of deadwood is only 5–10 % of that found in natural forests (Hahn and Christensen, 2005). Hence, forest management guidelines and forest certification programmes at local scales may require the abundance of woody debris to be maintained or increased (Sustainable Forestry Initiative, 2015). In the case of major forest damage, the Finnish Forest Act requires the removal of damaged trees. If the removed damaged wood is not considered in the carbon offset payment, the forest owner who has increased the wood stock will not benefit from their actions in the form of a carbon payment. On the other hand, the removed damaged wood does not improve the forest's carbon balance. The forest owner may have forest insurance that compensates for the trees

Table 1
Attributes of the carbon offset schemes.

Attribute	Levels of attributes
Initiator of the compensation arrangement	<ul style="list-style-type: none"> - My initiative - A familiar forest professional takes the initiative - A forest representative of the public authority takes the initiative - State tax resources.
Source of financing for compensation payments	<ul style="list-style-type: none"> - Carbon compensation payments paid by domestic companies. - Carbon compensation payments paid by foreign companies - Only damaged wood left in the forest is considered in the additional wood stock for carbon compensation
Considering damaged wood in carbon compensation	<ul style="list-style-type: none"> - All damaged wood left in and harvested from the forest is considered in the additional wood stock for carbon compensation
Amount of carbon compensation (€/m ³ , paid for the additional wood stock compared to the baseline forest volume, compensation paid every ten years)	<ul style="list-style-type: none"> - €2/m³ - €5/m³ - €10/m³ - €15/m³ - €20/m³ - €30/m³

Design: Bayesian D-efficient design.
9 sets in 4 blocks = 36 choice situations.

destroyed by forest damage, even if they are removed from the forest. Forest owners' attitudes towards considering the deadwood in the carbon offset payment are influenced, for example, by their perceptions of the likelihood of damage and of the fair allocation of costs arising from the damage.

Carbon compensation payments were expressed in euros per roundwood cubic metre of wood to provide forest owners with easily comparable information. The carbon mass is directly and linearly linked to the wood volume, and it can therefore be used as a proxy for increased aboveground carbon storage (Lehtonen et al., 2004).

In the survey, the forest owners were first presented with an introduction to the new potential carbon offset schemes and the four attributes followed by nine choice tasks, which were allocated to four blocks (in total, 36 choice tasks) (Table 2). Each task had three alternatives: two scheme alternatives and the status quo alternative, described as refusing to participate in either of the schemes. The status quo alternative was identical across the choice tasks. In the example in Table 2, carbon compensation levels are set to be the same when other attributes change. This single choice example is due to the optimal design received as a result of the soft survey launch procedure described in the next section.

3.3. Data

A sample of 10,000 forest owners with email addresses was extracted from the of the Finnish Forest Centre's Forest owner register. Forest owners were sampled from the register using database information on forest holding sizes and locations by province. All forest holdings were arranged in ascending order by size within each province, and interval sampling was applied from south to north to achieve the target sample size of 10,000. While the register provides reasonably comprehensive data on forest holdings based on National Land Survey records and airborne forest inventory methods, it is not complete regarding owner contact details and has gaps in email information. Typically, the email

Table 2
Example of choice task 1. Which carbon compensation arrangement would you choose if the features in the options are as follows? Tick one of the circles.

	Arrangement A	Arrangement B	I will not participate in the arrangement
Initiator of the compensation arrangement	A forest representative of the public authority is the initiator	A familiar forest professional is the initiator	I do not want to participate in either of these arrangements
Source of financing for compensation payments	Carbon compensation payments paid by domestic companies	Carbon compensation payments paid by foreign companies	
Considering damaged wood in carbon compensation	Only damaged wood left in the forest is considered in the additional wood stock for carbon compensation	All damaged wood left in and harvested from the forest is considered in the additional wood stock for carbon compensation	
Amount of carbon compensation (€/m ³ paid for additional wood stock compared to a baseline forest volume, paid every 10 years)	€15/m ³	€15/m ³	
I think the best option is	O	O	O

addresses of forest owners are collected in the register through forestry-related communication between forest owners and the Finnish Forest Centre. Without any update, when a forest owner dies, the heirs will have the deceased person as their contact information. In this study, the lack of email address information, especially for heirs, led to the systematic exclusion of their share (approximately 9–10 %) of forest holdings from the population.

An email containing personalized response links was sent to the respondents. The online survey form and optimization of the choice experiment design was implemented by the company SurveyEngine. The survey was launched with a soft launch procedure at the end of May 2023. In the first phase, the survey invitation was sent to 500 forest owners. The results were analysed and the priors for a Bayesian D-efficient design were defined. As the number of responses was still too small for a proper design optimization, in the second phase, the survey invitation was sent to 3000 forest owners, which resulted in an adequate number for optimization of the choice experiment design. Finally, the survey invitation was sent to 6500 forest owners. A total of three reminders with the optimized design were sent to all non-respondents of the 500, 3000 and 6500 subsets. A total of 1482 forest owners fully completed the survey, corresponding to a response rate of 14.8 %. This response rate is below average in comparison with previous similar studies conducted by post (Horne, 2006; Lindhjem and Mitani, 2012; Vedel et al., 2015) but in line with online surveys in which the respondents have been contacted via email (Hobbs and White, 2012; Mäntymaa et al., 2021).

The representativeness of the collected survey data was assessed by comparing them with the results from a large-scale representative survey of Finnish Family Forest Owners (Karppinen et al., 2020). The comparison table is presented in Appendix A, Table A8. In our study data, younger and middle-aged individuals were slightly over-represented, leading to an underrepresentation of pensioners.

Furthermore, respondents living in rural areas were underrepresented. Owners of large forest holdings responded more frequently than owners of small holdings. In terms of gender, men responded slightly more often than women. The limitations in representativeness were clearly related to contacting the respondents via email and the online survey format (see Leppänen and Halltia, 2023). Nevertheless, the data can be considered representative enough of the target population (excluding heirs) to provide a comprehensive view on Finnish forest owners' perceptions and preferences to be used in the modelling of the choice experiment responses. However, estimates of the percentage share of forest owners in different latent classes and other frequency distribution results should be considered with caution.

3.4. Socio-economic characteristics, contract features and attitudinal covariates

An overview of the socio-economic characteristics of the forest owners participating in the survey, as well as the carbon schemes characteristics and forest owners' attitudes towards CC is presented in Table 3. The average age of forest owners who responded was 60 years, 20 % of them were females and 64 % had completed higher education (college or university). Almost 60 % of the respondents answered that they had a valid forest insurance. The average forest area was 60 ha, and less than half of the owners reported a total household income higher than EUR 70,000.

To assess the influence of carbon offset scheme characteristics on the respondents' willingness to participate, they were asked, after the choice experiment part, to rate how much certain features influenced their willingness to join a carbon offset scheme (from 1, not at all, to 5, extremely). The main features reflected the financial incentives, flexibility and user-friendliness of the programme. The statements used to measure these features are illustrated in Fig. 1.

Table 3

Descriptive statistics for the variables used in the CL and LC models, grouped into socio-demographic factors, carbon programme characteristics and attitudinal variables among forest owners ($n = 1453$).

Variable name	Description	Type	Mean	SD	Median	Min	Max
<i>Socio-demographic factors</i>							
age	Age of forest owners in years	Continuous	60.46	12.44	62	24	103
female	(0 = Male, other, I don't want to say; 1 = Female)	Dummy	0.20	0.40	0	0	1
education	0 = Primary or elementary school, high school, vocational school, other; 1 = Polytechnic/university, College/university	Dummy	0.64	0.48	1	0	1
insurance	1 = Yes; 0 = No, I don't want to say	Dummy	0.58	0.49	1	0	1
forest_land	Forest area in hectares	Continuous	60	102.49	34	1	2000
high_income	0 = Income lower than EUR 69,999; 1 = Income higher than EUR 70,000	Dummy	0.43	0.50	0	0	1
<i>Carbon programme characteristics</i>							
financ_incent	Financial benefits and incentives, average (1 = not at all; 2 = slightly; 3 = to some extent; 4 = very; 5 = extremely)	Continuous	3.35	1.07	3.67	1	5
flexibility	Flexibility, average (1 = not at all; 2 = slightly; 3 = to some extent; 4 = very; 5 = extremely)	Continuous	3.61	0.96	3.67	1	5
user_friendly	User-friendliness and support, average (1 = not at all; 2 = slightly; 3 = to some extent; 4 = very; 5 = extremely)	Continuous	3.51	1.07	3.75	1	5
<i>Attitudinal variables</i>							
contr_CC	Contributing to the fight against climate change (1 = not at all; 2 = slightly; 3 = to some extent; 4 = very; 5 = extremely)	Categorical	2.86	1.15	3	1	5
mitigate	Intention to implement CC-mitigating forest management activities (1 = 0 or 1 activity; 2 = 2 or 3 activities; 3 = 4 or more)	Categorical	1.96	0.77	2	1	3
risk	I plan to take action to reduce the risks of CC in my forest over the next five years (1 = totally disagree and somewhat disagree, 2 = neutral, don't know; 3 = somewhat agree and totally agree)	Categorical	2.37	0.72	3	1	3

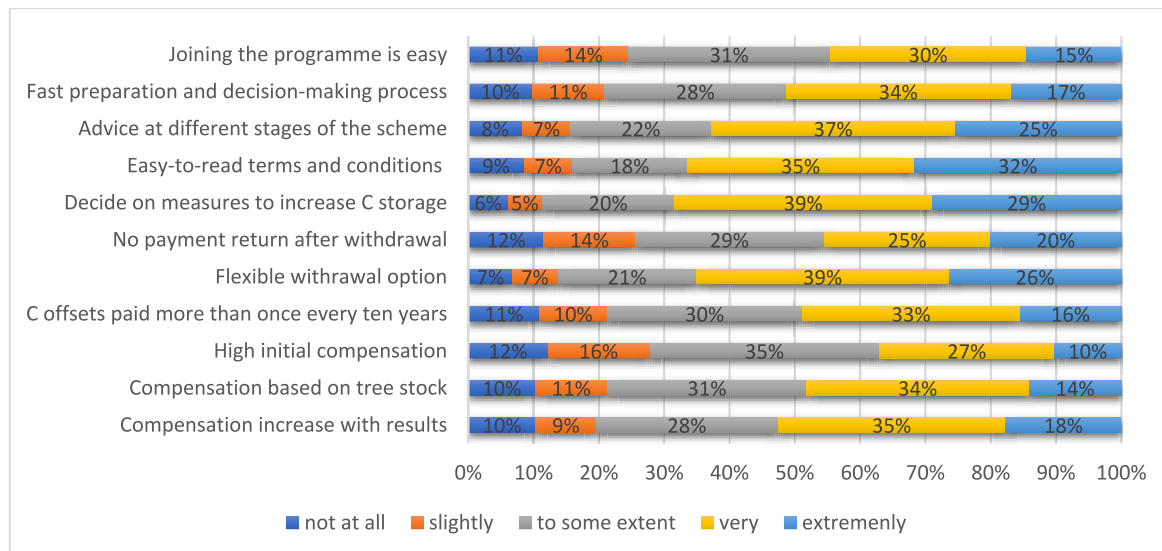


Fig. 1. Ranking by forest owner respondents of the programme characteristics that would increase their willingness to participate in carbon schemes.

The combined variable “financial benefits and incentives” was derived from the average of three statements related to higher compensation with better results, a high level of carbon compensation based on the volume of the tree stock and carbon offsets paid more than once every ten years. The internal consistency and hence the reliability of the three grouped statements was tested with Cronbach’s alpha, which suggested that the statements were closely related as a group ($\alpha = 0.9$). Similarly, “flexibility” was derived as the average of a set of three statements related to a flexible dismissal option, no need to return the initial payment in case of exiting the scheme and the possibility for the owner to decide on measures to increase carbon capture and storage. Cronbach’s alpha for *flexibility* was $\alpha = 0.77$. The variable “user-friendliness and support” was constructed by averaging the responses to four statements in relation to easy-to-read terms and conditions and instructions, the adequacy of advice in different stages of the scheme, a fast preparation and decision-making process and the ease of joining the scheme. Cronbach’s alpha for *user_friendly* was $\alpha = 0.92$.

Forest owners’ overall attitudes towards CC mitigation were assessed by having them rate the importance of the statement “contributing to the fight against climate change” as a factor in increasing their willingness to join a carbon offset scheme. In addition, it was tested whether forest owners’ intentions to manage their own forest for CC mitigation or reduce the CC risks in their forest was significantly different among the various latent classes.

3.5. Empirical models: conditional logit and latent class model

The analysis of DCE data is based on the principles of random utility theory (RUM), in which individual preferences are evaluated based on observed choices and a random utility function. The utility U_{ij} for individual i of alternative j consists of an observable component V_{ij} , which is determined by the attributes of the alternatives in a DCE and respondent characteristics, and a stochastic term ϵ_{ij} , which represents unobservable heterogeneity across the individual choices and alternatives.

$$U_{ij} = V_{ij} + \epsilon_{ij}, i = 1, 2, \dots, I; j = 1, 2, \dots, J \quad (1)$$

The conditional logit model (CL) developed by McFadden (1974), which is an extension of the multinomial logit model, has been widely used for analysing discrete choice data (Doherty et al., 2021; Kosenius, 2024; Zewdie et al., 2023). In this study, CL was estimated as the basic DCE model, which provides a useful starting point for the analysis. However, CL assumes homogeneous preferences for all individuals,

implying the need to apply another model that allows for the identification of distinct classes of individuals with similar preference structures.

Forest owners are not a homogeneous group; they exhibit diverse preferences for carbon offset programmes. Their preferences are affected by various socioeconomic backgrounds, risk perceptions, environmental attitudes and land management objectives. Conventional discrete choice models, such as multinomial logit (MNL), often assume that all respondents have the same preferences, which can oversimplify complex decision-making processes (Train, 2009). This study focuses on identifying classes of forest owners who share similar characteristics based on their preferences for results-based carbon offset schemes. For example, forest owners who are economically oriented and have a low interest in forest conservation or CC mitigation will favour the status quo, as they are generally resistant to new forest management changes. The inclusion of damaged wood in the additional growing stock for carbon compensation is expected to encourage participation, as it provides cost-saving benefits. Additionally, carbon payments are anticipated to be the primary motivating factor for forest owners to engage in carbon offset schemes.

To achieve this, a latent class (LC) model (Boxall and Adamowicz, 2002) was employed to explore the diversity in forest owners’ preferences towards results-based carbon offset schemes. In the LC model, respondents were categorized into classes according to their behaviours, and a choice model was developed separately for each class. The classes identified through the LC provide valuable insights into the profiles of forest owners who are most likely to accept or reject carbon offset programmes. For example, one class might consist of financially driven forest owners, who see carbon offset programmes as a way to generate income from their land, while another class might be made up of environmentally conscious landowners. The preferences are assumed to be homogeneous in each class, but the preferences vary among classes. Additionally, alternative-specific constants (ASC) were integrated to identify any consistent choice patterns not accounted for by the attributes in the LC model.

The LC model groups the respondents into a number of classes, K , based on their behaviour, and a choice model was estimated for each class. The prior probability of individuals being in one of the K classes is estimated as a model parameter together with the class-specific utility parameters. To find the appropriate number of classes, both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were used (Greene and Hensher, 2003).

The LC model employed in this study is based on a logit model that

estimates the probability that scheme alternative j is chosen by forest owner i in a given choice scenario t , as shown in Eq. (2):

$$P_{it,q}(j) = \frac{H_{iq} \exp(x'_{it,j} \beta_q)}{\sum_q H_{iq} \exp(x'_{it,j} \beta_q)} \quad (2)$$

where H_{iq} is the prior probability that forest owner i belongs to latent class q . Class assignment can be defined using a multinomial logit model based on observed variables, which represents the probability that forest owner i belongs to class q as a function of individual specific characteristics z_i (Greene and Hensher, 2003):

$$H_{iq} = \frac{\exp(z'_i \theta_q)}{\sum_q \exp(z'_i \theta_q)}, q = 1, \dots, Q, \theta_Q = 0 \quad (3)$$

where z'_i denotes a set of observable characteristics that enter the model for class membership. The Q th parameter vector is normalized to zero to secure identification of the model (Greene and Hensher, 2003, Chapter 21). The LC model was estimated with the maximum likelihood approach and the analysis was performed in 'R' software (R Core Team, 2022) using the 'gmm1' package (Sarrias and Daziano, 2017).

The attitudinal variables and contract features were, however, not included in the LC model to avoid endogeneity, but the differences between respondent classes formed in LC analysis are examined in section 4.2. All attribute levels, except for carbon compensation, were coded as dummy variables. An alternative specific constant (ASC) was included in the model and is equal to 1 if the respondent chose the "no carbon offset scheme" alternative and 0 if one of the two carbon scheme alternatives was chosen. According to the CL model, the positive and significant ASC indicates that forest owners were more likely to choose the status quo,

hence showing a preference for no carbon offset schemes over participating in new carbon schemes. Forest owners were more likely to join a scheme if it was suggested by a familiar forestry professional rather than initiated on their own. They preferred emission offset payments paid by domestic or foreign companies over those funded by state taxes and favoured schemes that account for the removal of damaged wood in the payment.

For the LC model, the optimal number of classes was determined by minimizing the Bayesian information criterion (BIC).

4. Results

4.1. CL and LC model results

Table 4 presents the results from the CL and LC models. Table 3 in section 3.4 provides detailed descriptive statistics and an explanation for each variable used in both the CL and LC models. Class 1 comprises 10 % of the respondents (Table 4). The respondents in this class were attracted to schemes that are initiated by a familiar forestry professional and favoured companies as the source of funding for payments rather than state taxes. They preferred schemes that account for removed damaged wood and they would opt for higher carbon compensation. A little less than half (32 %) of the respondents belong to class 2. The ACS was positive and higher compared to all other classes, indicating respondents' preference for the status quo. Individuals in this group were more likely to join a new scheme motivated by their own initiative than forest experts. Similarly to class 1, they were also more willing to join a scheme if the carbon payments are higher. Class 3 consists of 15 % of the respondents who, unlike those in classes 1 and 2, were less likely to choose the status quo. They were more likely to join a carbon scheme if it is initiated by a familiar forestry professional, while they were less likely

Table 4
Conditional logit (CL) model and latent class (LC) model results.

Variables	CL	Latent Class Model				
		Class 1	Class 2	Class 3	Class 4	Class 5
Class probability		10 %	32 %	15 %	20 %	24 %
ASC SQ	Coef. 1.868***	Coef. 3.275***	Coef. 5.868***	Coef. -2.584***	Coef. 0.107	Coef. 2.908***
<i>Initiator of the compensation arrangement (base: own initiative)</i>						
A familiar forest professional	0.296***	0.306**	-0.787***	0.293***	0.386***	0.210**
A forestry expert from the public sector	0.052	0.104	-1.118***	-0.016	0.208**	-0.130*
<i>Source of financing for compensation payments (base: state tax resources)</i>						
Emission offset payments paid by domestic companies	0.330***	2.920***	-0.140	0.080	0.301***	0.296***
Emission offset payments paid by foreign companies	0.264***	3.869***	0.505*	-0.148*	-0.036	0.123
<i>Considering damaged wood in carbon compensation (base: Only damaged wood left in the forest is considered in the additional wood stock for carbon compensation)</i>						
All damaged wood left in and harvested from the forest is considered in the additional wood stock for carbon compensation	0.804***	0.439***	0.383	-0.329***	1.369***	0.653***
Amount of carbon compensation	0.028***	0.130***	0.092***	0.048***	0.302***	0.123***
<i>Socio-demographic factors</i>						
intercept			-2.438***	-2.535***	-2.567***	-1.458***
age			0.064***	0.054***	0.048***	0.034***
female			0.185*	-0.224*	0.620***	0.475***
education			-0.637***	-0.599***	-0.104	-0.249**
insurance			0.105	0.143	0.673***	0.593***
forest_land			0.003***	0.003***	0.002**	0.004***
AIC		17,101				
BIC		17,542				
N. obs.	13,077	13,077				
log likelihood	2578	-8491				

Z-test: *** 99 % significance level; ** 95 % significance level; * 90 % significance level.

Design: Bayesian D-efficient design.

9 sets in 4 blocks = 36 choice situations.

to participate if emission offset payments are paid by foreign companies and removed damaged wood is considered. Higher carbon compensations had a positive effect on willingness to participate.

Class 4 has a predicted share of around 20 % (Table 4). Respondents in this group were more likely to join a carbon scheme if it is initiated by a familiar forestry professional or public sector experts rather than on their own initiative. They preferred schemes to be funded by domestic companies, and they supported accounting for the damaged wood removed from the forest holding, as well as higher carbon payments.

Class 5 is the second biggest class (24 % of the respondents; Table 4). Respondents in this class, like those in classes 1 and 2, tended to prefer the status quo over new schemes. They were more likely to participate if the scheme is initiated by a familiar forestry professional and less likely if initiated by a forestry expert from the public sector. They favoured domestic company-funded payments and supported accounting for damaged wood removed from the forest holding. In class 5, and in fact across all classes, higher carbon payments increased the likelihood of respondents participating in a carbon scheme with high significance levels.

Regarding the effects of socio-economic variables on the willingness to participate in a carbon offset scheme, it is important to note that class 1 serves as the reference group, which in terms of the magnitude of preference parameters is the most moderate group (Table 4). Therefore, interpreting statistically significant coefficients suggests that an individual is more (or less) likely to belong to a given class compared to belonging to class 1.

Older forest owners were more likely to belong to classes 2, 3, 4 and 5, while younger individuals were more likely to belong in class 1 (Table 4). Female forest owners and those with a larger forest area were more likely to belong to all four classes compared to class 1. Forest owners who had completed higher education were less likely to belong to classes 2, 3 and 5. Respondents with insurance were more likely to belong to classes 4 and 5.

4.2. Contract features and attitudinal characteristics

The differences in the pro-active contract features and attitudinal characteristics between respondent classes formed in LC analysis were analysed in detail (Table 5). The least significant difference (LSD) test provides a pairwise comparison of the means and was used for this analysis. The results of the test are presented in Table 5 and indicate significant differences between the classes across all variables.

For financial incentives, classes 1, 3, 4 and 5 had similarly high scores, indicating no significant differences among them (a), while class 2 scored significantly lower (b), indicating that forest owners in class 2 were not very highly motivated by financial incentives.

Regarding user-friendliness, class 4 stands out with the highest score, which was only significantly different from class 2. The mean score in class 2 was significantly the lowest, indicating that user-friendliness would slightly affect the respondents' willingness to participate in a carbon scheme. Similar results were obtained for the flexibility of the schemes.

Table 5

Class-specific means of the contract features and attitudinal characteristics.

	Class 1	Class 2	Class 3	Class 4	Class 5
Financial incentive	3.82 a	2.46 b	3.63 a	3.81 a	3.76 a
User-friendly	3.96 a,b	1.70 c	3.78 b	3.98 a	3.81 b
Flexibility	3.77 a,b	3.12 c	3.70 b	3.86 ab	3.88 a
Mitigate	2.14 a	1.69 c	2.07 a,b	2.18 a	1.99 b
Risk	2.51 a,b	2.13 c	2.38 b	2.58 a	2.41 b
Contribute to CC mitigation	3.21 a,b	2.17 d	3.15 b	3.38 a	2.97 c

The labelling (a–d) indicates which means in the pairwise comparisons do not differ in the LSD test at the 0.05 significance level. Classes have the same letter if their means are not significantly different.

The mean score for the intention to implement CC-mitigating forest management activities (Mitigate) was significantly lower in classes 2 and 5. Regarding risk reduction actions in forests, class 2 had significantly the lowest score, followed by classes 3 and 5. The intention to contribute to CC mitigation was also significantly the lowest in class 2, followed by class 5 and then by class 3. A brief summary of the class characteristics is presented in Table 6.

4.3. Willingness to accept (WTA)

Forest owners' WTA estimates (i.e., compensation requests) for each attribute were estimated based on the LC model (Table 7). WTA for each attribute was estimated as the ratio between the coefficient for each attribute and the price coefficient (Boxall et al., 1996).

In particular, the WTA for attribute j in class q is defined in Eq. 4, and it represents the relative effect of the single attribute j on the necessary price premium to be paid for forest owners' willingness to accept for a unit change in the attribute:

$$wt\alpha_{qj} = - \frac{\hat{\beta}_j}{\beta_{carbon,q}} \quad (4)$$

where $\beta_{carbon,q}$ is the individual marginal utility of money, as measured by the carbon compensation parameter. The confidence intervals were calculated using the delta method (Bliemer and Rose, 2013). The highest WTA for a familiar forestry professional to suggest an arrangement is around €9/m³ for class 2, while the highest WTA for a forestry expert from the public sector as the initiator also belongs in class 2. WTA for emission offset payments paid by domestic companies was highest in class 1. The confidence intervals indicate that there is high heterogeneity among the forest owners.

A negative WTA suggests that respondents in a latent class are willing to accept less compensation for a certain attribute included in the scheme compared to the base. For example, emission offset payments made by foreign companies, followed by those made by domestic companies, displayed the highest negative values. This implies that forest owners in Class 1 would be willing to accept €30 and €22 less, respectively, compared to the base case (state tax resources).

Regarding the WTA derived from the ASC SQ, it was found to be large and negative, which was anticipated considering that the ASC itself is large and positive, indicating a strong preference for the status quo. This suggests that forest owners would require less compensation to leave the status quo, reinforcing the idea that non-monetary factors (such as the administrative burden, trust issues or risk aversion) may be major barriers to participation in carbon offset schemes. The absolute value of WTA is large, because the ASC captures all unobserved preferences for the status quo rather than just a specific attribute effect.

Table 7 also presents WTA for one policy scenario based on the results of the CL. The attribute levels with the most significant results were chosen. The policy scenario includes a familiar forest professional as the initiator, emission offset payments paid by domestic companies and all damaged wood left in and harvested from the forest being entitled to additional inventory. Class 2 exhibits the highest WTA, which was expected given that this class showed the strongest support for the status quo, according to the results of the LC model. Conversely, Class 3 displays the lowest WTA, which is consistent with their strong preference for the carbon scheme over the status quo.

5. Discussion

Compensation for increasing the amount of carbon sequestered by forests is an essential policy tool to reduce GHG emissions worldwide. A number of studies have quantitatively examined factors that influence the interest of family forest owners in participating in carbon offset programmes. The most frequently examined factors have been forest owners' socio-economic characteristics (e.g., age, gender, education,

Table 6
Structured summary of the latent class (LC) model results in a comparative format.

Scheme attributes and owner features	Class 1 (Company funding)	Class 2 (Status Quo Favouring, Own Initiative)	Class 3 (Scheme Favouring, Expert-Led)	Class 4 (Public & Taxpayer Funding)	Class 5 (Familiar Professional, Domestic Funding)
Status Quo (ASC)	Moderate preference	Strong preference	No preference	Non-significant	Moderate preference
Preferred Scheme Initiator	A familiar forestry professional	Own initiative	A familiar forestry professional	Both a familiar & public sector professional	A familiar forestry professional
Preferred Funding Source	Domestic & foreign companies	Foreign companies	Taxpayers	Domestic companies	Domestic companies
Response to Carbon Price	Higher price increases appeal	Higher price increases appeal	Higher price increases appeal	Higher price increases appeal, more than in other classes	Higher price increases appeal
Considering all damaged wood in carbon compensation	Supports	No strong impact	Opposes	Supports	Supports
Demographics	Younger, smaller holding, higher education	Older, middle-sized holding, lower education	Older, male, middle-sized holding, lower education	Older, female, insured, smaller holding, higher education	Older, female, insured, larger holding

Table 7
Willingness to accept (€/m³) for the LC model of the significant attributes.

Variables	Latent Class Model				
	Class 1	Class 2	Class 3	Class 4	Class 5
Class probability	10 %	32 %	15 %	20 %	24 %
ASC SQ	-25.20 [-30.02, -20.3]	-63.82 [-77.29, -50.35]	54.21 [30.66, 77.77]		-23.66 [-25.25, -22.06]
A familiar forestry professional	-2.35 [-4.49, -0.21]	8.56 [2.33, 14.79]	-6.14 [-10.36, -1.91]	-1.28 [-1.94, -0.61]	-1.71 [-2.94, -0.46]
A forestry expert from the public sector		12.15 [4.92, 19.40]		-0.70 [-1.29, -0.09]	1.06 [-0.16, 2.28]
Emission offset payments paid by domestic companies	-22.45 [-25.10, -19.81]			-0.10 [-1.60, -0.40]	-2.40 [-3.56, -1.24]
Emission offset payments paid by foreign companies	-29.75 [-35.33, -24.17]	-5.49 [-11.39, 0.40]	3.11 [-0.60, 6.82]		
All damaged wood left in and harvested from the forest is entitled to additional inventory	-3.37 [-5.40, -1.34]		7.00 [4.16, 9.64]	-4.54 [-5.43, -3.64]	-5.31 [-6.43, -4.19]
Policy scenario (WTA difference of no programme and programme with attributes at level 1)	-3.00 [-6.44, 0.46]	69.70 [55.00, 84.43]	-53.45 [-76.00, -31.00]	-6.46 [-8.45, -4.47]	14.23 [10.65, 18.00]

income, land area), scheme attributes (e.g., carbon payments, contract length, level of difficulty of joining or withdrawing) and forest owners' perceptions of contributing to CC mitigation.

This study revealed that there is heterogeneity in forest owners' preferences for the features of a results-based carbon offset scheme, and different scheme characteristics, such as pro-active contract features, attract different types of forest owners. The characteristics of forest owners most willing to enrol in a carbon offset scheme were also analysed. The findings regarding carbon payments appear to be in line with the general findings in the literature (Dickinson et al., 2012; Håbesland et al., 2016; Miller et al., 2012; Soto et al., 2016; White et al., 2018). Carbon payments were the only attribute found to have a significantly positive effect across all classes.

Almost one-sixth of respondents (15 %) had a pro-reform attitude (class 3), while the majority of classes were pro status quo, which was anticipated considering that forest owners are generally sceptical about new programmes and the commitments that these programmes might entail. Several studies have indicated that choice experiments often reveal a status quo bias, where respondents prefer existing conditions over proposed changes. This bias is influenced by factors such as the

number of alternatives, the complexity of choices and the perceived similarity between options (Carson et al., 2020; Oehlmann et al., 2017; Scarpa et al., 2007).

The largest of the latent classes (class 2, 32 % of respondents) would be less willing to participate in schemes initiated by a familiar forestry professional or a forestry expert from the public administration than if they were the initiators themselves. Schemes initiated by the public administration may be associated with bureaucratic hurdles, paperwork and rigid rules, which can discourage participation, while forest owners prefer to have the flexibility and freedom to take their own initiative. However, in classes 1, 3, 4 and 5, the scheme being suggested by a familiar forestry professional has a positive effect, indicating that forest owners often have established relationships with local forestry professionals, which increases the sense of trust and reliability. Forestry professionals typically have in-depth knowledge of local forest conditions. Therefore, forest owners may believe that they also have knowledge of the most favourable financial measures, and this might be another reason for the positive effect.

Carbon schemes funded by companies are preferred in classes 1, 4 and 5, possibly because they are often seen as financially more stable

than those relying solely on the government or smaller, less predictable sources of funding. Another reason may be that many forest owners want minimal public spending on forestry, and private contributions are therefore preferred. Including all damaged wood, both harvested and left in the forest, as additional stock for carbon compensation had a positive impact on forest owners in classes 1, 4 and 5, suggesting that these groups are financially motivated. However, in class 3, forest owners were less likely to participate if compensation included all removed damaged wood following a disaster. This may reflect concerns that the removal of damaged wood is not aligned with climate change mitigation efforts. Interestingly, in class 2, factors such as contributing to the fight against CC and the intention to implement multiple CC mitigation activities in forest management scored significantly lower than all the other classes. This low score in this class might be attributed to forest owners' concerns regarding the commitment that comes with these schemes, the potential costs that the mitigation actions may entail, as well as the potential forgone income from timber harvesting or other land uses. Some forest owners may not view CC mitigation as their responsibility or may believe that large corporations or governments should be leading these efforts rather than individual landowners. Forest owners in class 2 might perceive financial incentives as insufficient or uncertain, leading to scepticism about whether participation in carbon offset schemes is truly beneficial or worth the effort. Overall, this class describes a group of forest owners who lack trust in forestry experts and have a negative attitude towards the potential benefits of participating in a carbon offset scheme.

The LC model results indicated that sociodemographic factors played a significant role in the class assignment. Older, female, less educated forest owners having forest insurance and a larger area of forest land were more likely to belong to classes 4 and 5. Age has been shown to positively predict the willingness of forest owners to accept incentive payments to forgo harvesting for the sake of habitat protection (Kline et al., 2000) and the value they place on environmental certification (Thompson and Hansen, 2012). This positive relationship may be attributed to the decreasing interest among aging forest landowners in harvesting timber, making them more inclined towards less intensive management options (Favada et al., 2009).

The results of this study are in line with numerous other studies suggesting that women are more likely to hold positive attitudes regarding forest conservation and regeneration practices (Agarwal, 2009), certification (Thompson and Hansen, 2012) and carbon offset practices (MacKerron et al., 2009). However, Alhassan et al. (2019) observed that the willingness to accept carbon schemes was higher for male than for female forestland owners. The results regarding the impact of education contrast with the findings of previous studies, which have demonstrated a positive association with the willingness to participate (Dickinson et al., 2012; Markowski-Lindsay et al., 2011). The negative sign for education in this study may indicate that less educated forest owners have fewer income-generating options. Hence, they might view carbon offset schemes as a valuable and low-risk opportunity to supplement their income.

There are conflicting results in the literature regarding the impact of land size on willingness to participate, with Khanal et al. (2017) reporting a positive effect, while Thompson and Hansen (2012) observed a negative effect. According to the results of this study, across all classes, forest owners with a larger forest area tend to be more willing to participate. It is rational that farmers who have larger areas to manage could benefit more from carbon payments considering that they would be able to sequester higher amounts of carbon. Regarding the scheme characteristics, there was little heterogeneity in the responses and the scores were high overall, which is in line with the literature.

WTA prices were not very high in all classes, and in many cases, WTA estimates were even negative. Because of the hypothetical nature of the survey, some respondents may have over- or underestimated the WTA (Lloyd-Smith and Adamowicz, 2018). Low or negative WTA estimates could mean that the respondents would require less compensation than

expected to accept a certain change. This can imply that they may even see the change as beneficial or neutral and they do not therefore demand a high premium to accept it. In choice tasks, the contract term was in practice fixed to only ten years, which evidently also decreases potential losses. Latent class analysis helps to reveal the respondents preferring the status quo and having a high WTA.

Based on the results of this study, financial incentives, particularly higher carbon prices, are critical in encouraging participation across all classes, highlighting the importance of economic incentives. However, engagement in carbon offset markets is not uniform. The majority of respondents displayed a strong preference for the status quo, suggesting that overall participation in carbon offset programmes may be limited. Finnish forest owners are a heterogeneous group, with some classes (2 and 5) having a lower intention to implement CC-mitigating forest management activities compared to the rest of the classes. Considering that classes 2 and 5 are the two largest classes, Finnish forest owners would possibly not be very willing to manage their land specifically to increase carbon storage and sequestration.

6. Conclusions

Forests are anticipated to play a crucial role in reducing GHG emissions, especially in Finland, which is heavily forested. However, because most of these forests are privately owned, it will be necessary to incentivize landowners. Therefore, understanding their preferences for different carbon sequestration programme features is essential for securing their participation and designing economically efficient programmes. Nonetheless, there has been limited research on the preferences of forest landowners or their willingness to accept payments to participate in results-based schemes (Danley, 2019).

The latent class model revealed significant diversity among Finnish forest owners in their attitudes towards carbon offset schemes. This suggests that a one-size-fits-all policy would probably be ineffective. Instead, tailored approaches considering the differing preferences of each class could improve participation. However, compensatory payments appear to be the only attribute that motivates respondents across all classes to participate in carbon schemes. Additionally, schemes initiated by a familiar forest professional were preferred by the majority of classes. Therefore, to achieve higher participation rates, this attribute could be considered in the design of schemes. Hence, another policy implication could be to enhance extension services and motivate forest owners to participate in training and education initiatives. The percentage shares of forest owners in different latent classes derived in our study are not exact estimations for all Finnish family forest owners, as heirs were not included our data, and older forest owners in particular were slightly underrepresented. The email survey format disfavors the oldest and to some extent also rural forest owners, which has to be considered when interpreting the latent class percentage shares.

In this study, we examined the impact of contract features on forest owners' willingness to join the voluntary carbon scheme. The analysis is limited to the forest owners' own evaluation of the features increasing the desirability of the schemes, even though some type of randomised controlled trial approach could have been built into the survey set-up to provide more information on the impact of the features on forest owners' choices. In future research, this approach, as well as analysing the real-life carbon schemes, would provide more insights on the best ways to design effective carbon schemes. Further research could also focus on investigating the WTA for carbon offset schemes in other European countries with similar forest ownership structures, enabling cross-country comparisons. Once such schemes are introduced, it would be recommended to conduct longitudinal studies to monitor changes in the attitudes and behaviour of forest owners.

CRedit authorship contribution statement

Domna Tzemi: Writing – review & editing, Writing – original draft,

Methodology, Investigation, Formal analysis, Data curation. **Jussi Leppänen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **Hilja Autto:** Writing – review & editing, Data curation, Conceptualization. **Emmi Haltia:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

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

Appendix A. Appendix

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Table A1. Mean estimation of age (years) across the latent classes.

Classes	Mean	SE	[95 %_Conf Interval]	
1	53.17606	0.9648864	51.28334	55.06878
2	63.32096	0.5841094	62.17517	64.46675
3	62.01485	0.8641386	60.31976	63.70994
4	60.68136	0.6683196	59.37038	61.99233
5	58.61517	0.6440488	57.3518	59.87853

Number of obs = 1453.

Table A2. Mean estimation of forest land area (hectares) across the latent classes.

Classes	Mean	SE	[95 %_Conf Interval]	
1	47.31261	4.511906	38.46206	56.16316
2	60.09969	5.302985	49.69736	70.50202
3	60.21307	8.634808	43.27504	77.1511
4	51.45593	3.169685	45.23828	57.67358
5	70.99084	6.273419	58.68491	83.29677

Number of obs = 1453.

Table A3. Tabulation of latent classes and the variable 'female'.

Latent_class	female		
	0	1	Total
1	83.80	16.20	100.00
2	82.31	17.69	100.00
3	88.61	11.39	100.00
4	73.22	26.78	100.00
5	76.40	23.60	100.00
Total	80.04	19.96	100.00

Pearson Chi² = 23.57, Prob = 0.0001.

Table A4. Tabulation of latent classes and the variable 'education'.

Latent_class	education		
	0	1	Total
1	30.28	69.72	100.00
2	42.14	57.86	100.00
3	41.58	58.42	100.00
4	29.49	70.51	100.00
5	32.02	67.98	100.00
Total	35.86	64.14	100.00

Pearson Chi² = 20.13, Prob = 0.0005.

Table A5. Tabulation of latent classes and the variable 'insurance'.

Latent_class	insurance		
	0	1	Total
1	50.70	49.30	100.00
2	47.38	52.62	100.00
3	46.53	53.47	100.00
4	33.22	66.78	100.00
5	34.83	65.17	100.00
Total	41.64	58.36	100.00

Pearson $\chi^2 = 28.40$, Prob = 0.0000.

Table A6. Tabulation of latent classes and the variable 'mitigate'.

Latent_class	mitigate			Total
	1	2	3	
1	21.13	43.66	35.21	100.00
2	47.38	35.59	17.03	100.00
3	23.27	45.54	31.19	100.00
4	20.00	41.69	38.31	100.00
5	30.06	40.73	29.21	100.00
Total	31.66	40.26	28.08	100.00

Pearson $\chi^2 = 96.97$, Prob = 0.0000.

Table A7. Tabulation of latent classes and the variable 'risk'.

Latent_class	risk			Total
	1	2	3	
1	11.27	26.06	62.68	100.00
2	23.36	39.30	37.34	100.00
3	12.87	35.64	51.49	100.00
4	6.10	29.49	64.41	100.00
5	12.08	34.83	53.09	100.00
Total	14.45	34.41	51.14	100.00

Pearson $\chi^2 = 81.56$, Prob = 0.0000.

Table A8. Comparison of some essential background features of this survey and the representative Finnish Family Forest Owner 2020 survey (percentage shares, %). Heirs have been excluded by calculation from the Forest Owner 2020 survey to improve comparability. The numbers of respondents for each background question (n) are included for both surveys.

	This survey (2023, internet survey)	Forest Owner 2020, excluding heirs (2019, mail survey)
Type of ownership	<i>n</i> = 1889	<i>n</i> = 6007
Alone or with spouse	85	81
Partnership	15	19
Major occupation	<i>n</i> = 1487	<i>n</i> = 5942
Wage earner	41	38
Agricultural and/or forestry entrepreneur	9	9
Other entrepreneur	8	6
Retired	40	45
Other (unemployed, student, at home)	2	2
Residence	<i>n</i> = 1490	<i>n</i> = 5847
Countryside	49	54
Small or large rural settlement	20	17
Urban area	31	29
Sex	<i>n</i> = 1473	<i>n</i> = 5779
Male	79	77
Female	21	23
Age, years	<i>n</i> = 1490	<i>n</i> = 5861
–44	12	13
45–54	18	14
55–64	29	23
64–74	29	33
75+	12	17

(continued on next page)

(continued)

	This survey (2023, internet survey)	Forest Owner 2020, excluding heirs (2019, mail survey)
Forest holding size class, hectares	<i>Forest holding defined within the whole country, n = 1936</i>	<i>Forest holding defined within a province, n = 6005</i>
5–9	9	15
10–24	26	31
25–49	25	24
50–99	21	18
100–199	13	8
200–	6	4
Total, %	100	100

Appendix B. The carbon compensation scheme presented for the respondents in the survey

B.1. Carbon compensation scheme, where you can choose the most suitable methods for yourself

Would you participate in a carbon compensation scheme and under what conditions?

Imagine that you could participate in a carbon compensation scheme where you receive a reward for increasing the carbon stored in the forest stand compared to conventional forest management practices.

- Joining the programme applies to the entire holding and is agreed upon with an authority representative.
- *You can freely decide how to manage the forests* on the holding to increase the amount of carbon stored in the forest stand. You can delay thinning and final fellings, or you can perform uneven-aged forest management cuttings instead of final fellings. You can also grow a denser forest stand than usual or fertilize the forests on the holding.
- Forest owners can be generally informed about the possibility of joining the programme, or it can be suggested to you personally either by a familiar forestry professional or a public administration forestry expert.
- The programme can be funded either from tax revenues or by collecting funding from domestic or foreign companies' emission compensation fees.

Compensation is based on the additional growing stock and deadwood accumulated on the holding

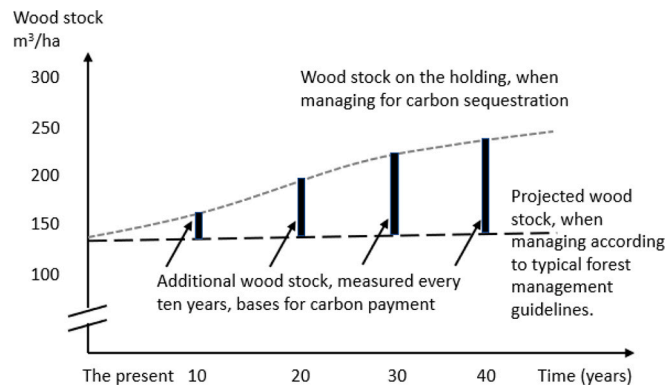
- After joining the programme, the volume of forest stand (m^3) on the holding is assessed. Additionally, a development forecast for the forest stand is prepared, predicting the development of the forest stand volume if you manage and perform cuttings according to the most commonly used typical commercial forest management recommendations.
- The volume of growing stock and deadwood is measured every ten years and compared with the forest stand volume according to the typical development forecast in forest management guidelines. If the volume of the forest stand exceeds the forecast, **additional wood stock** has formed on the holding.
- Note that you may have already managed your forests in such a way that the stock is already larger at the starting point than if the forest had been managed according to the typical forest management guidelines. In this case, maintaining the forest stand for at least ten years may be sufficient to receive compensation.
- You can perform cuttings while participating in the carbon compensation scheme and receive income from timber sales. However, cuttings may reduce the amount of carbon compensation you receive. If you perform all cuttings according to the typical forest management guidelines, no additional forest stand will form, and no carbon compensation will be paid for the holding.

Considering forest damage

- If the holding is affected by forest damage, the damaged wood left in the forest is included in the wood stock on which the compensation is based.
- Depending on the details of the arrangement, carbon compensation can also be paid for removed damaged wood (e.g., the volume of salvage cuttings in the storm damage area, m^3).

Carbon compensation

- After joining the programme, you will receive an initial holding-specific compensation payment of €500.
- Carbon compensation (€ per m^3) is paid for the additional wood stock that exceeds the volume according to the typical development forecast in forest management guidelines.
- The volume of wood stock (living and dead wood) is measured, and the carbon compensation based on the measured additional wood stock is paid for **the first time after ten years and then every ten years to the current forest owner**.
- Carbon compensation is taxable capital income from forestry.
- You do not need to worry about inflation, as the amount of future carbon compensation is tied to the consumer price index.



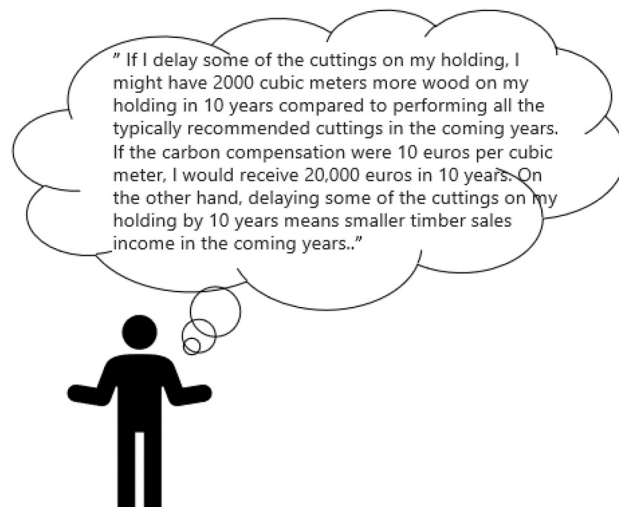
Exiting the carbon compensation arrangement

- If you want to exit the arrangement during the first ten-year period, you must repay the initial compensation payment (€500) received when joining the programme.
- If the owner of the holding participating in the carbon compensation arrangement changes during the ten-year period, the arrangement transfers to the new owner. If the new owner wants to exit the carbon compensation arrangement during the first ten-year period, they must repay the initial compensation (€500).

Example calculation

The hectare-specific example calculation below illustrates how the amount of carbon compensation and additional forest stand would affect the compensation payment received by the forest owner. The level of carbon compensation varies because the goal is to determine at what level of compensation forest owners are willing to increase the amount of carbon in their forests.

Example				
Carbon payment, every 10 years €/m³	Additional wood stock on holding, average m³/ha			
	10	50	100	150
2	20 €	100 €	200 €	300 €
5	50 €	250 €	500 €	750 €
10	100 €	500 €	1 000 €	1 500 €
15	150 €	750 €	1 500 €	2 250 €
20	200 €	1 000 €	2 000 €	3 000 €
30	300 €	1 500 €	3 000 €	4 500 €



Choice tasks

Next, we present nine choice situations, each with two arrangements for the carbon compensation programme, A and B. The attributes of arrangements A and B differ, as the goal is to determine under what arrangements you would be willing to increase or maintain the amount of carbon in the forests on your holding. Compare the attributes of the arrangements and choose the best arrangement for yourself in each of the nine choice situations. If neither arrangement option seems good to you, you can choose the option ‘I do not want to participate in the arrangement.’

Table B1. Final nine choice sets in four blocks. Initiator: 0 = own initiative, 1 = a familiar forestry professional, 2 = a representative of the public administration. Funding source: 0 = state budget, 1 = domestic companies, 2 = foreign companies. Damage: 0 = all damaged wood left in and harvested from the forest is included, 1 = only damaged wood left in the forest is included. Compensation level: euros/m³ for additional wood.

Choice situation	Arrangement A (option 1)				Arrangement B (option 2)				Neither (option 3)	Block
	Initiator	Funding source	Damage	Compensation level	Initiator	Funding source	Damage	Compensation level		
4	2	1	1	15	1	2	0	15		1
5	2	2	1	10	0	1	0	10		1
10	2	2	1	15	1	0	0	15		1
13	0	2	0	30	1	0	1	30		1
14	2	2	0	2	1	0	1	5		1
15	1	0	1	2	0	1	0	2		1
18	0	0	1	5	1	1	0	5		1
30	1	2	0	10	0	1	1	10		1
33	1	1	0	20	2	2	1	20		1
1	0	0	0	15	1	1	1	10		2
6	1	2	1	10	0	1	0	15		2
7	1	0	0	10	2	2	1	5		2
11	1	1	1	20	2	0	0	20		2
27	2	0	0	15	1	2	1	15		2
29	0	0	1	20	2	1	0	20		2
32	2	1	0	30	0	0	0	30		2
34	0	1	1	2	2	2	1	5		2
35	0	0	0	5	1	2	1	2		2
3	0	1	0	5	2	0	1	2		3
9	0	1	0	30	2	0	1	30		3
12	2	0	1	30	1	2	0	30		3
22	1	1	0	5	0	0	1	2		3
24	0	2	1	2	2	0	0	15		3
25	0	2	0	10	1	1	1	10		3
28	1	0	0	15	0	2	1	10		3
31	1	0	1	30	2	1	0	30		3
36	2	1	1	2	1	2	0	30		3
2	2	2	0	20	0	0	1	20		4
8	1	0	0	30	0	2	1	5		4
16	1	1	1	2	2	0	0	2		4
17	1	2	0	20	0	1	1	20		4
19	2	0	0	20	0	1	1	15		4
20	2	1	1	5	0	2	0	5		4
21	0	2	1	15	2	0	0	20		4
23	0	2	1	10	2	1	0	10		4
26	2	1	1	5	1	2	0	2		4

Data availability

Data will be made available on request.

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