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Review Paper

Enhancing engagement: A European meta-analysis of forest owner preferences in voluntary agreements for the provision of biodiversity and ecosystem services

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ABSTRACT

European forests are increasingly expected to provide a wide range of biodiversity and ecosystem services (BES) beyond timber production, positioning non-industrial private forest (NIPF) owners (hereafter, "forest owners") as key contributors. An emerging question is how to engage forest owners in the needed forest management shift. To better understand the drivers of forest owner participation in voluntary agreements, we conducted a meta-regression analysis of 24 studies from survey-based, stated, or actual participation data, encompassing 28 distinct datasets and 571 observations from 12 European countries. The findings suggest that certain contract designs substantially enhance forest owner participation: short- and mid-term contracts of 1 to 30 years (as opposed to longer-term agreements), the inclusion of withdrawal clauses, non-restrictive management requirements, and higher compensation levels all promote uptake. Moreover, agreements centred on biodiversity, carbon, or forest multifunctionality attract higher participation than timber- or water-focused aims. Although trust between the actors is often considered important in the literature, we did not consistently detect such effects on participation rates. The results indicate a more consistent interest among forest owners in BES agreements after 2012, especially those centred on biodiversity and carbon aims as well as on multifunctionality, potentially reflecting broader policy trends and shifts in motivation among younger generations of forest owners, moving away from timber production. These insights offer practical lessons for policymakers and practitioners aiming to design effective, targeted incentives that leverage Europe's privately owned forests to meet biodiversity and climate objectives.

1. Introduction

1.1. Complex forest provision demands in a changing environment

Historically, the European forest governance landscape was defined by large coalitions focusing on the production of timber to sustain a steady yield for the industry (Farrell et al., 2000; Sotirov & Storch, 2018). The main support that non-industrial private forest (NIPF) owners (hereafter, "forest owners") received through subsidies was directed towards timber production and advisory services, with an emphasis on afforestation and the development of economic management capacities (Sotirov & Storch, 2018).

Expectations and demands on European forest owners to put more weight on multifunctional forest management have grown rapidly, increasing pressure from policymakers and society on forest owners (Pülzl et al., 2017; Sotirov et al., 2019). These increasing demands for timber products and forest biodiversity and ecosystem services (BES) are often in direct competition with each other (Blattert et al., 2023). Hence, defining appropriate forest management strategies to mitigate climate change, while simultaneously grappling with the impacts of climate change on forests' provisioning capabilities, is developing into difficult trade-offs that policy makers are facing (Lindner et al., 2014).

1.2. Untapped potential of Europe's privately owned forests

One often-discussed option to support increasing BES demands is

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voluntary management agreements to activate currently untapped reserves for the provision of BES. From 1990 to 2015, the proportion of European privately owned forest area gradually increased by 22 % (FOREST EUROPE, 2015, 2020; Weiss et al., 2019b) and reached 61 % by 2015 within the EU-28 (FOREST EUROPE, 2020) with 90 % of the private forest holding less than 10 ha (EFI, 2021). This large share and considerable increase in private forest ownership stresses the importance of forest owners, including smaller landowners, as an important stakeholder group for supplying BES.

The share of timber removals compared to net forest increment in Europe is estimated to be around 66 % in 2022 (Eurostat, 2024b). The share of logging carried out by different actors varies widely across countries, ranging from predominantly state-driven to primarily private-driven timber production (Eurostat, 2024b). However, evidence shows that the extracted timber per hectare and year is relatively low when it comes to smaller private forest owners (Schmithüsen & Hirsch, 2010; Tiebel et al., 2021).

In addition, forest multifunctionality indicators in European forests have been estimated to be below 50 % of their maximum potential for timber, biodiversity and carbon sequestration (Van Der Plas et al., 2018). Even though demand and potential exist, volatile net revenues and underdeveloped markets for ecosystem services (FOREST EUROPE, 2020) are barriers to entrepreneurial and innovative forestry practices. Consequently, the strong potential to enhance the provision of BES places policymakers in a key position to develop instruments that support BES and promote multifunctional forests. On the European level, the European Commission (EC) increased its emphasis on the engagement of forest owners and land managers in providing BES (European Commission, 2020, 2021). Voluntary agreements, such as payments for ecosystem services (PES) or other owner-driven actions, are highly valued tools for increasing forest owner engagement, as they are undertaken at the discretion of the property owners. They offer an effective means to enhance the provision of BES, reduce conflicts over management requirements, and build trust between issuers and land owners (Miljand et al., 2021).

1.3. Awareness, trust and motivation increase engagement in BES management

To tap into the potential of BES provision by forest owners, policymakers must understand what motivates them in order to design effective conditions for participation (Deuffic et al., 2018; Weiss et al., 2019a). Obtaining this information is a crucial part of the policymaking process, as demonstrated by numerous past efforts that failed to motivate and increase the mobilization of timber in privately owned forests (Lawrence, 2018). The underlying assumption in the design of voluntary agreements for forest management is that forest owners can be encouraged and motivated to change their management behaviour through the provision of information and resources such as financial incentives (Boon et al., 2010; Mitani & Lindhjem, 2015).

European studies assessing forest owner motivation and behaviour revealed heterogeneous interests (Follo et al., 2017; Pülzl et al., 2017; Deuffic et al., 2018; Ficko et al., 2019; Sotirov et al., 2019; Weiss et al., 2019b; Wilkes-Allemann et al., 2021; Juutinen et al., 2022). Many forest owners hold strong conservation values that go beyond the financial interests of owning their forest (Domínguez & Shannon, 2011; Feliciano et al., 2017; Tiebel et al., 2021). Furthermore, shifts towards more urban lifestyles, lower dependencies on forest incomes and changing interests in forest management approaches may continue to alter the provision of BES from forests (Wiersum et al., 2005).

A further discussed aspect affecting forest management decisions is trust between the contract partners and implementation managers. Evidence shows that trust can influence participation rates in voluntary agreements (Boakye-Danquah & Reed, 2019), however, not all collaborations have a positive effect on engagement (Brouwer et al., 2015; Miljand et al., 2021; Villamayor-Tomas et al., 2021).

Growing interest in forests' capability to promote planetary health has encouraged especially younger and well-educated forest owners to adopt management practices that include biodiversity protection measures and climate change adaptions (Toppinen et al., 2019; Husa & Kosenius, 2021), suggesting a generational shift in forest management. From a policy side, the European forest is expected to play a key role as a carbon sink to support climate neutrality goals by 2050 (Korosuo et al., 2023), as well as in achieving the goals of the European biodiversity strategy for 2030 (Lier et al., 2022). Although expectations for forest owners to provide BES have clearly increased, it remains unassessed whether the growing emphasis on multifunctionality has affected participation in voluntary agreements.

1.4. Hypotheses and research aims

European forests are complex socio-ecological systems governed by overlapping institutions (Ostrom, 2009; Carlisle & Gruby, 2019). This complexity can raise transaction costs for forest owners through monitoring, information search, or uncertainty (Williamson, 1996). To increase participation, effective voluntary agreements should therefore aim to reduce these costs through levers such as short durations, withdrawal flexibility, simplified management requirements and compensations.

Beyond economic incentives, forest owner decisions are also shaped by intrinsic motivations (Ryan & Deci, 2000). Agreements that help preserve autonomy (e.g., shorter terms, withdrawal options) and align with stewardship values (e.g., biodiversity protection, carbon sequestration) are expected to raise participation, potentially even at lower compensation levels. Based on these insights and the empirical outline presented, three hypotheses were tested:

- Voluntary agreements focusing on biodiversity protection and carbon sequestration achieve higher participation rates at similar or lower compensation levels compared to timber-focused agreements, reflecting the broader environmental motivations of forest owners.
- Forest owner participation rates are higher if they are informed about the contract parties and collaborators.
- An increase in forest owner interest in participating in voluntary agreements for BES can be detected over the last three decades.

Further, the most common contract design attributes were collected to define and control where transaction costs may play a role. The results aim to help European policymakers better engage forest owners and align forest management with the European Forest and Biodiversity Strategy (European Commission, 2020, 2021). To synthesize recent findings despite methodological and contextual differences, a meta-regression was applied to identify key factors influencing participation across diverse contexts.

2. Methods

2.1. Literature search

The literature was collected in July 2024 through a systematic online literature search of the Scopus, EconLit and Web of Science databases and was pre-registered on the Open Science Framework (OSF) [https://osf.io/5hku4/]. The search focused on the participation of forest owners in voluntary forest management agreements and followed the PRISMA principles of systematic reviews and meta-analysis (Page et al., 2021). The search query had three main foci: (i) voluntary agreements, (ii) owner definition, and (iii) in-text mentions of words describing overall participation (used to calculate participation rates). To ensure that results were relevant to the forestry domain, all papers were searched for the term "forest" in the title, abstract or keywords of the document. The search query was built based on these rules, using the following string:

(ALL ("voluntary forest conservation" OR "forest*management program*" OR "PES" OR "payment for ecosystem service*" OR "business model*" OR "market based incentive*" OR "MBI") AND ALL ("private forest owner" OR "private land owner" OR "NIPF" OR "small forest owner") AND ALL ("engage*" OR "particip*") AND TITLE-ABS-KEY ("forest") AND PUBYEAR (> 1993)).

The search results were filtered to cover results from the last three decades (1994–2024), which were considered the most relevant to determine whether today's forest owners will enter into an agreement. Furthermore, only peer-reviewed papers, conference papers and book chapters written in English were considered, to ensure accessibility and a high quality of the reported information. The system boundary was defined as the European continent. The full list of studies can be found in Appendix A.

2.2. Model description

The meta-regression method is a common approach to quantitatively evaluate the outcomes of a collection of primary studies (Harrer et al., 2022). To examine the variables influencing participation rates, a three level meta-regression was conducted using the *rma.mv* function from the {metafor} package version 4.6.0 (Viechtbauer, 2010) in R 4.3.1 (R Core Team, 2023). This model accounts for multiple estimates within studies and for dependencies across observations by incorporating two levels of random effects (Harrer et al., 2022). These effects balance the differences in the number of observations per dataset. The model is specified as:

$$\widehat{\theta_{ij}} = \theta + \beta x_{1,i} + \beta x_{2,i} + \beta x_{3,i} + \beta x_{4,i} + \beta x_{5,i} + \zeta_{(2)ij} + \zeta_{(3)j} + \epsilon_{ij} \tag{1}$$

where:
i: individual observation of effect size (nested in *j*);
j: dataset level cluster of effect size;
$\widehat{\theta_{ij}}$:estimate of the true effect size θij;
θ: intercept;
$\beta_1,\ldots,\beta_5$: coefficients for the moderators, grouped as:

- methodological differences
- contract design
- programme aim
- contract partner
- timber price

x: moderators.
$\zeta_{(2)ij}$:within-cluster heterogeneity (level 2);
$\zeta_{(3)j}$: between-cluster heterogeneity (level 3);
ε_{ij}: sampling error of individual observation.

2.3. Effect size

The dependent variable, or effect size, is defined as the common outcome variable across the collected datasets: the observed participation rate in voluntary forest management agreements. It was derived from primary studies of real and hypothetical BES agreements as a continuous variable ranging from 0 to 1, ensuring consistency and comparability across observations (Harrer et al., 2022). The following methods were used to extract or estimate the participation rates, depending on the data provided by the primary sources:

Dichotomous choice surveys involved collecting "yes" or "no" responses from landowners regarding their participation in an existing programme or their willingness to participate in a modified or hypothetical programme. Reported participation rates were collected where provided; otherwise, participation rates were calculated as the proportion of respondents who indicated an intention to enrol. This method produced 24 observations from 9 surveys.

Choice experiment surveys asked forest owners repeatedly to choose their preferred program from multiple alternatives (choice sets). Each alternative was described by a set of attributes (e.g., payment levels, management requirements), whose specific values changed across choices. Each choice experiment survey thus created multiple hypothetical scenarios, every scenario representing a unique combination of program attributes.

The probability of participation in each hypothetical scenario was estimated using coefficients obtained from the original studies. These coefficients capture how changes in program attributes influence the likelihood of participation. Participation probabilities were derived using a binary logit model (2) derived from Mitani & Lindhjem (2022):

$$\boldsymbol{P_j} = \frac{\boldsymbol{exp}(\beta' \boldsymbol{x_j})}{\{\boldsymbol{exp}(0) + \boldsymbol{exp}(\beta' \boldsymbol{x_j})\}} \tag{2}$$

where:
P: probability of participation in scenario *j*;
β: vector of attribute coefficients collected from the primary study;
xj: vector of attribute values for scenario *j*.

The non-participation option was modelled with a baseline utility of zero, ensuring the interpretation of *β* as attribute effects relative to non-participation. For studies that used random parameter estimates (e.g. mixed logit models), mean values of these parameter distributions were used as point estimates to facilitate comparability across different methodologies. This method produced 541 observations from 15 datasets.

Census registration and other sources: For studies using census data or other sources of actual participation in real programmes, reported participation rates were used when available. If not explicitly provided, participation rates were calculated as the percentage of landowners enrolled in the programme, based on reported participant numbers. This method produced six observations from four datasets.

2.4. Standard errors

Because the studies varied in sample size, their estimates differed in precision. A standard error variance was used to weight each effect size accordingly. As the primary studies did not directly report their standard errors, two methods were employed to approximate them, a model-based estimation and a proportional estimation:

Model-based estimation: Standard errors for participation rates derived from choice experiment datasets were estimated from the 95 % confidence intervals per scenario, calculated from the primary studies using the binary logit model (2) and the reported standard errors per coefficient. Specifically, standard errors were approximated by dividing the full width of these confidence intervals (upper limit minus lower limit) by 3.92, corresponding to 2*1.96, the approximate width of a 95 % normal confidence interval (Chandler et al., 2019). This model-based approach was applied to 507 out of 571 observations, corresponding to 13 out of the 28 datasets.

Proportional estimation: When no information required for the model-based estimation of the standard error was available in the primary data source, it was approximated through the participation rate using the following approach as outlined in Harrer et al. (2022):

$$SE = \sqrt{\frac{p(1-p)}{n}} \tag{3}$$

where:
SE: standard error;
p: participation rate in the voluntary agreement;
n: sample size for participation questions.

2.5. Random effects

Several papers provided results from different countries; these results were considered as different datasets. Hence the random effect applied is on the dataset level, rather than the study level. To account for the hierarchical structure of the data and unobserved heterogeneity, two levels of random effects were included in the meta-regression model:

Dataset-level random effect (Level 3): Captures variability between different datasets.

Estimation-level random effect (Level 2): Accounts for potential dependencies among estimates within the same dataset.

By specifying these random effects, the model effectively balanced the differences in the number of observations per study and controlled for intra-study correlations, ensuring more accurate and reliable estimates of the overall participation rate. The inclusion of the individual observation level as random effect was supported by the model's significantly improved fit, as indicated by reductions in the Akaike information criterion (AIC) and increases in the log-likelihood. The model parameters were estimated using the restricted maximum likelihood (REML) method, which reduces potential biases for nested data. The intercept β_0 represented the pooled participation rate for a null case in which all dummy variables were set to 0, moderator factors were set to their reference level, and continuous variables were set to their mean. The continuous variables (timber price and compensation amount) were demeaned before analysis. To account for the influence of data collection methods on participation rate (Fowler, 2013), this study differentiated between data collection methods and included a factor that distinguished real agreements from hypothetical ones. A dummy variable was used to control for the two standard error estimation approaches.

2.6. Temporal evaluation

In addition to the primary meta-regression analysis, a final evaluation was conducted to assess temporal shifts in participation differences over time. For this evaluation, the dataset was divided into two subsets: one constrained to data collected before 2013 (b2013) and another to data collected starting from 2013 onwards (f2013) following the implementation of the European forest strategy in 2013 (European Commission, 2013). This approach enabled the examination of how participation rates and preferences evolved over time, while controlling for key programme attributes.

2.7. Model initialization

Two distinct meta-regression models were developed to examine the factors influencing participation rates. Model 1 includes methodological, contract design, and motivational moderator variables, along with control variables, such as a dummy variable for the standard error estimation and inflation-adjusted timber prices. Model 2 builds upon the first model by incorporating monetary incentive moderator variables and a dummy variable distinguishing between annual and lump-sum payments. To address the increased risk of collinearity resulting from reduced number of observations and studies in Model 2, the methodological variables were excluded. However, a side-by-side comparison was conducted as a sensitivity analysis.

The base level of Model 1 represents a voluntary contract with a duration of 1 to 10 years, no option to withdraw, silvicultural management requirements, and a general focus on timber provisions. It was assumed that the identity of the contract partners was not revealed in the survey and that the timber export prices were at their average values. The programme was non-hypothetical, information was obtained by choice experiment, and standard error was estimated through the model-based approach. For Model 2, the initialization variables were kept the same. Differences were the removal of the methodological variables (survey method and hypothetical agreements), the addition of two continuous compensation variables, both initialized at their average values, and a payment frequency dummy variable set to lump-sum payment.

3. Results

3.1. Descriptive literature review

The database search resulted in 126 records (Fig. 1). One study (Mitani & Lindhjem, 2022) was identified that contained other relevant literature sources for Europe, which were manually added to the database, resulting in 139 studies. Of these, 12 duplicates were removed. Following a title and abstract scan, 74 studies were removed which either did not have a European focus, did not focus on non-industrial private forest owners, evaluated other instruments than voluntary agreements or were non-English. Finally, a full-text evaluation led to the exclusion of another 29 studies that were either not relevant to the research questions or did not provide consistent information to estimate participation rates. This procedure resulted in 24 studies that were considered relevant for the quantitative analysis (Appendix A).

Twenty-eight separate datasets were extracted from these 24 studies, providing 571 observations. Sample size was between 137 and 9690 forest owners (mean = 1613, median = 1429). The studies were published between 2006 and 2024, with data collection conducted between 2000 and 2020. The search yielded research findings conducted in 12 European countries and with 7 different programme aims (Fig. 2). The Northern European region was most represented in the dataset, especially Finland (8) and Denmark (5) (Fig. 2 left). Five specific and two unspecific BES aims were collected. The aims were grouped based on the primary programme goal communicated to the forest owners, independent from the required actions to be fulfilled within the contract. Following selection criteria derived from the reviewed studies: i) *Timber-focused agreements* included attributes explicitly promoting timber production (studies 1, 2, 20) (grouping referenced in Appendix A) or stated participation in timber production (3). ii) *Biodiversity-focused agreements* comprised biodiversity increases on forest plot (1, 2), specific biodiversity-enhancing commitments such as increasing deadwood or retaining old trees (4, 5, 19), conservation aligned to explicitly mentioned biodiversity strategies (5), afforestation with a biodiversity emphasis (12, 20), as well as general forest conservation with biodiversity the main reason (6, 14, 16–19, 21, 22). iii) *Carbon sequestration agreements* focused explicitly on carbon offset initiatives or increasing carbon storage (1, 2, 15). iv) *Recreation agreements* included agreements allowing recreation infrastructure development or full public access on the forest plots (8, 12, 13, 19). v) *Water-focused agreements* targeted groundwater protection (12). vi) *General unspecified ecosystem services* (GES) encompassed voluntary agreements without explicitly defined BES aims, such as forest conservation without explicitly stated aims, landscape preservation, or risk reduction (1–3, 7, 9, 11, 19, 23). Finally, vii) *Multifunctional agreements* combined two or more explicitly defined BES goals in a single agreement, excluding non-specific GES aims (1–3, 19, 20, 24) (Study references in Appendix A). In most countries biodiversity protection was surveyed (10), followed by timber production (7), and multifunctional agreements (7) (Fig. 2, right).

Several differences in the data collection method and outreach strategies were recorded (Table 1). The data was mainly produced through choice experiment surveys (53 %), followed by dichotomous choice surveys (32 %). For one data source, participation rates were collected through census data. Most of the evaluated agreements were hypothetical (68 %). Stated participation was used in five datasets (18 %), and actual participation in four (14 %). To contact the forest owners, post-mail (32 %) or post-mail outreach in combination with another method (18 %) were the strategies most often applied, followed by web-based contact (14 %) and other data collection methods (14 %).

Biodiversity protection appeared as a key focus in research on voluntary BES agreements throughout all three decades, reflecting continuous research interest. A shift in research foci towards forest multifunctionality and BES such as carbon sequestration can be seen

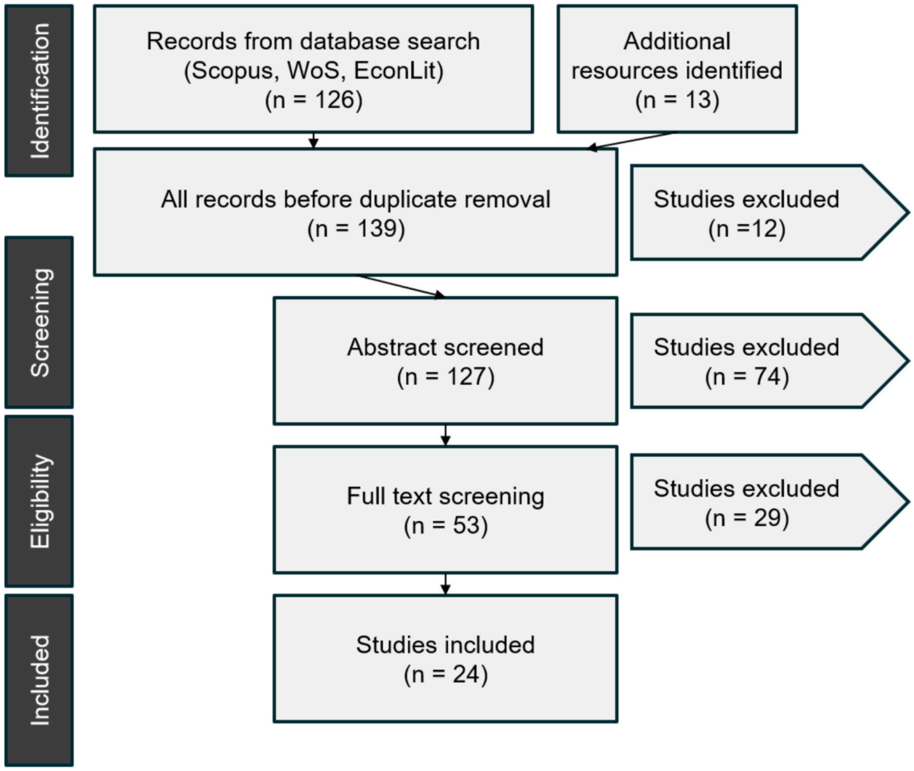

Fig. 1. Systematic literature review flowchart, adapted from Moher et al. (2009).

starting in 2012. Timber-focused agreements were not present in our results until 2011 (Fig. 3), possibly due to the focus of the search terms on the provision of BES, which are a relatively modern term (Haynes-Young and Potschin, 2012; UNECE, 2007). One study involving five separate surveys in different European countries is notable (Juutinen et al., 2022). Sample sizes remained relatively stable over the years.

Four overarching contract characteristics were identified. Firstly, two types of compensation: i) annual payments and ii) one-time lump-sum payments which were found equally often (Table 2). Compensation was inflation adjusted to 2015 levels based on national harmonized indices of consumer prices (HICP) (Eurostat, 2024a). Compensation averaged 2013 EUR (median = 1664 EUR) per hectare for one-time lump-sum payments and 509 EUR (median = 242 EUR) per hectare for annual payments. Secondly, contract lengths ranging from 0 to 100 years, with eight datasets also including the evaluation of a form of perpetual engagement. Thirdly, contract withdrawal options, where six studies considered withdrawal options, some with conditions such as monetary penalties for an early exit of the agreements. In five datasets, the non-availability of withdrawal options was explicitly stated. Finally, contractual management restrictions or requirements were summarized into three broad categories; i) *silvicultural management*, used when forest operations were part of the contract such as thinning, harvesting, shrub clearing or planting. ii) *conservation* representing set aside practices, bans on silvicultural operations, dedicated forest land left unmanaged or contractually agreed temporary forest conservation as well as delays in cuttings. Conservation requirements were the most common (36 %), followed by silvicultural management (31 %). For one-third of the produced observations a clear definition of the required management could not be included, they were categorized respectively. As a proxy for the association of contract partners, it was defined whether the respondents were informed of the specific people or agencies they would have the agreement with. Half of the datasets included this information (Table 2). For revealed participation, knowledge of contract partners was assumed. To measure the association of the timber markets on forest owner participation in BES agreements, average roundwood export prices were included as a control variable. The timber price data was retrieved from UNECE (2021), and inflation was adjusted to the respective year and country.

All variables were tested for significant effects on participation rates; detailed results are presented in Appendix B. All variables showed significant differences except for isolated lump-sum payments. However, when they were considered jointly with annual payments, both variables demonstrated significant effects on participation rates, and thus both were retained for the meta-regression analysis.

3.2. *Meta-regression*

Two distinct meta-regression models were developed and evaluated to examine the factors influencing participation rates. Model 1 includes 571 observations from 28 datasets. Model 2 builds upon the first model by incorporating monetary incentive moderator variables and a dummy variable distinguishing between annual and lump-sum payments, reducing the sample to 561 observations from 22 datasets. A summary of the dependent variable (participation rate) and the moderator variables used in the meta-regressions is provided in Appendix C.

3.2.1. *Statistics*

Both models employed a three-level random effects structure, with level three representing dataset-level clusters and level two representing the individual participation rates (see section 2.2). In Model 1, the pooled overall participation rate was estimated at 54 % (95 % CI: 25.2–83.2 %), with variance components τ^2_Level 3 = 0.0424 and τ^2_Level 2 = 0.0095. This indicates that 81 % (I^2 level 3) of the total variation was attributable to between-cluster heterogeneity, and 18 % (I^2 level 2) to within-cluster heterogeneity.

Model 2 estimated a higher pooled participation rate of 81.5 % (95 %

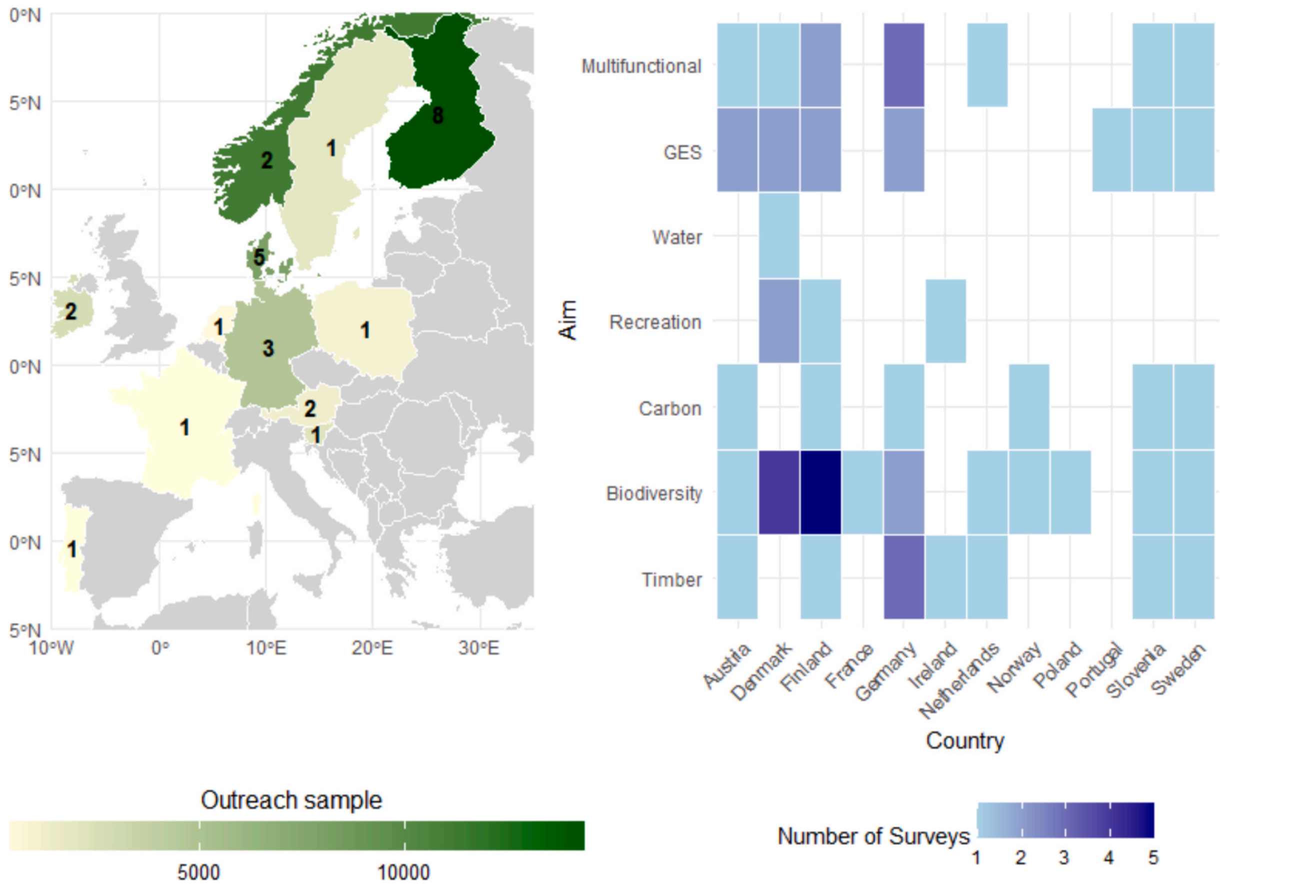

Fig. 2. Sample sizes of contacted or reported forest owners and number of datasets collected per country (left); heatmap of the number of datasets collected per country and aim (right). GES = general ecosystem services; Multifunctional: contracts combining two or more biodiversity or ecosystem services.

Table 1
Characteristics of the datasets used in the meta-regression.

Characteristics (number of datasets)	Count	Frequency (%)
Data collection method (28)		
Dichotomous choice survey	9	32
Choice experiment survey	15	53
Census	1	4
Other[a]	3	11
Participation types (28)		
Hypothetical[b]	19	68
Stated participation	5	18
Actual participation	4	14
Survey instruments (28)		
Post-mail	9	32
Web	4	14
Interview	3	11
Census	3	11
Post-mail and other	5	18
Other	4	14

[a] Reported planned afforestation and occurred afforestation in one combined variable, reported cluster analysis, mix between choice experiment and dichotomous choice survey.
[b] Hypothetical schemes refer to agreements which were not available PES programmes in the surveyed region.

CI: 53.2–100.1 %), with variance components τ^2_Level 3 = 0.0243 and τ^2_Level 2 = 0.0029. Here, 89 % (I^2 level 3) of the total variation was due to between-cluster differences, and 11 % (I^2 level 2) to within-cluster heterogeneity. Additionally, Model 2 demonstrated a better fit, as evidenced by lower AIC, BIC, and corrected AIC (AICc) values compared with Model 1. For both models, a logit-transformed dependent variable was regressed as well (Appendix D). However, due to the better fit of the raw participation rate (AIC and BIC), a good fit of the residuals, and the similar result outcome, the decision was made not to transform the dependent variable. This additionally facilitates a clearer communication of the results. Multicollinearity diagnostics via variance inflation factor (VIF) evaluation (Appendix E) and robustness tests using common regression techniques (Appendix F) generally confirmed the stability of results. Notably, the meta-regression method yielded more conservative significance estimates than other tested models.

3.2.2. *Contract design*

Five contract design features were included in the meta-regression. Table 3 presents the expected effect of each variable, indicating either the impact of applying a categorical factor or the effect of a unit increase for continuous variables.

Contract duration: The shortest contracts, lasting between 1 and 10 years, were preferred over other contract durations. Changing from short contracts to contracts ranging from 21 to 30 years resulted in a higher preference over 11 to 20 years agreements, but with a considerable overlap in their 95 % confidence interval (Fig. 4). Longer contracts evaluated (31–50 and 51–100 years) were the least preferred. In model 2, perpetual contracts had a higher preference compared to contracts lasting longer than 51 years. However, the regression results for perpetual contracts were only marginally significant ($p > 0.1$).

Withdrawal rights: Compared to the baseline of an explicit no-withdrawal agreement, conditional and full withdrawal availability were preferred in both models. With an effect between + 8 % and + 10 %, this variable had a considerable positive association on participation rate. Contracts which did not specify withdrawal rights did not significantly differ from contracts without withdrawal rights.

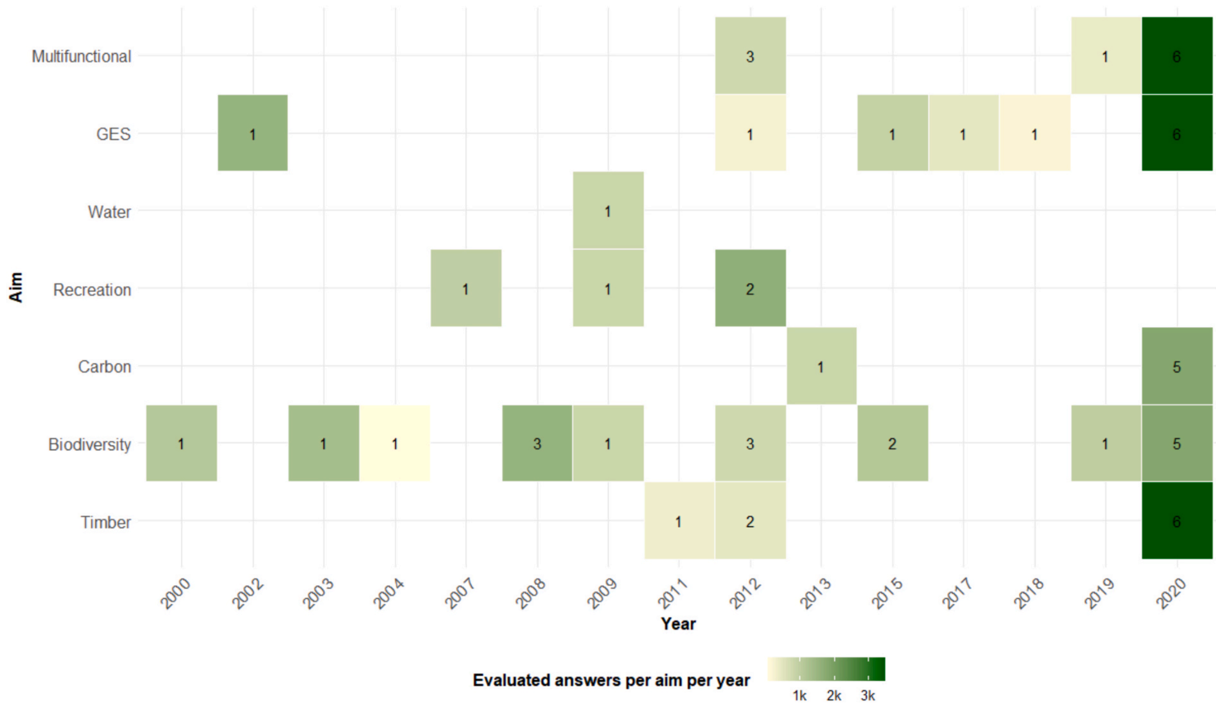

Fig. 3. Heatmap of sample size by programme aim and year. The number in each cell represents the number of datasets (surveys, census, etc.) included. GES = general ecosystem services; Multifunctional = contracts combining two or more biodiversity or ecosystem services.

Table 2
Programme characteristics and demographics.

Characteristics (number of datasets)	Count	Frequency (%)
Compensation (22)*		
Lump-sum (mean 2013 EUR)	11	50
Annual (mean 509 EUR)	11	50
Withdrawal option (9)*		
Available (AV)	3	33
Conditionally available (Cond_AV)	1	12
Not available (NS)	5	56
Management options (28)*		
Conservation	13	36
Silviculture	11	31
Unspecified management (NS)	12	33
Contract partner (28)*		
Defined	14	50
Not defined	14	50
Demographics		
Demographic variable (number of datasets)		Average
Gender (% male) (21)		79
Age (year) (22)		56
Average holding size (ha) (21)		55
Income from forestry (% yes) (4)		47
Participation in forest owner association (% yes) (4)		62

* Not all the datasets provided all variables listed while others provided more than one option; therefore, the number of datasets differ among characteristic categories. Demographic variables were collected; however, they were excluded from the regression analysis. Compensation is inflation adjusted to 2015 levels (Eurostat, 2024a).

Management requirements: Compared with the base level, which required silvicultural interventions by the forest owners, contracts without management requirements were the most preferred, with a participation rate increase of 13 %. Required conservation management measures were not significantly different from silvicultural measures in model 1. Conservation management measures decreased participation in model 2 by roughly 5 %.

Compensation: The meta-regression results confirmed that increasing compensation increased participation rates, as expected. An increase of 1000 EUR per ha in annual compensation above the mean corresponded to an increase of 34 % in participation rate. The same 1000 EUR increase in compensation above the mean made as a lump-sum payment corresponded to a 9 % increase in participation rate over contracts with lump-sum payments at the mean value. In terms of

Table 3
Meta-regression results.

Term	Model 1 (28 Datasets, 571 Observations) Estimate		SE	Model 2 (22 Datasets, 561 Observations) Estimate		SE
Intercept	0.542	***	0.147	0.815	***	0.144
MethodDC[a]	−0.016		0.153	–	–	–
MethodOther[a]	0.170		0.173	–	–	–
Hypothetical_Yes[b]	0.120		0.122	–	–	–
SE_Dummy1[c]	−0.198		0.131	−0.117		0.083
Contract11-20[d]	−0.129	***	0.039	−0.135	***	0.029
Contract21-30[d]	−0.088	***	0.019	−0.079	***	0.014
Contract31-50[d]	−0.288	***	0.027	−0.231	***	0.022
Contract51-100[d]	−0.282	***	0.026	−0.283	***	0.017
ContractPerpetual[d]	−0.100		0.090	−0.120	.	0.072
ContractNS[d]	−0.268		0.215	–	–	–
WithdrawAV[e]	0.081	***	0.022	0.084	***	0.014
WithdrawCondAV[e]	0.099	**	0.033	0.077	***	0.020
WithdrawNS[e]	−0.079		0.128	−0.127		0.101
MPConservation[f]	−0.043		0.032	−0.046	*	0.021
MPNS[f]	0.128	***	0.029	0.127	***	0.020
AimBiodiversity[g]	0.077	***	0.023	0.101	***	0.016
AimCarbon[g]	0.059	.	0.032	0.081	***	0.022
AimRecreation[g]	0.012		0.033	0.038	.	0.021
AimWater[g]	−0.647	***	0.045	−0.642	***	0.031
AimGES[g]	0.046	.	0.026	0.069	***	0.017
AimMultifunction[g]	0.069	**	0.023	0.080	***	0.017
Partner_Yes[h]	0.073		0.090	0.075		0.091
Timber_price[i]	0.101		0.281	0.262		0.213
Comp_annual[j]	–	–	–	0.338	***	0.015
Comp_lump-sum[j]	–	–	–	0.094	***	0.009
Dannual1[k]	–	–	–	−0.226	*	0.089
Loglik	336.2902			548.2959		
Deviance	−672.58			−1096.59		
AIC	−620.58			−1046.59		
BIC	−508.665			−939.395		
AICc	−617.88			−1044.05		
I^2 Level 2	18.28 %			10.52 %		
I^2 Level 3	81.43 %			88.92 %		
I^2 Total	99.72 %			99.44 %		

Significance: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$,. $p < 0.1$.
[a] Method: Data collection method, baseline: choice experiment, DC: dichotomous choice; [b]Dummy variable for hypothetical agreements; [c]Dummy variable for standard error (SE) estimation method 1 = proportional estimation; [d] Contract duration, baseline: 0–10 years, Perpetual = contract with no time limit, NS = not specified; [e]Options to withdraw from contract, baseline: no option to withdraw, AV = available, CondAV = conditionally available, NS = not specified; [f]Management practice, baseline: silvicultural management, NS = not specified; [g]Contract aim, baseline: timber production, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services; [h]Dummy variable if identity of contract partner is known; [i]Inflation- and country-adjusted demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough) (1 unit = 100EUR) (Eurostat, 2024a; UNECE, 2021); [j]Demeaned and inflation-adjusted (Eurostat, 2024a) compensation in EUR/ha (1 unit = 1000EUR); [k]Dummy variable for annual payments. SE = standard error.

preferences on the frequency of payments, annual payments were less preferred than lump-sum payments overall, with a roughly 23 % lower participation in programmes with annual payments.

Fig. 4 illustrates the contract design variables, highlighting their effects relative to the baseline scenario.

3.2.3. Motivations and external influences

Programme aims: In Model 1, agreements with biodiversity, water and multifunctional aims were positively significant ($p < 0.01$), while those with carbon and GES aims were marginally positively significant ($p < 0.1$). With the inclusion of the compensation variables in Model 2, the agreements focused on biodiversity, carbon, water, GES and multifunctional aims were highly and positively significant ($p < 0.001$). Agreements with recreation provision aims showed a marginally significant positive effect ($p < 0.1$).

Agreements emphasizing biodiversity (Model 1: +8%, Model 2: +10 %) and multifunctionality (Model 1: +7%, Model 2: +8%) were associated with the highest increases in participation rates compared to timber-focused contracts.

Agreements promoting carbon sequestration (Model 1: +6%, Model 2: +8%), recreation (Model 1: NS, Model 2: 4 %), and GES (Model 1: +5%, Model 2: +7%) also presented positive, though smaller, effects relative to timber-focused agreements. Finally, water-protection-focused agreements stood out because of their negative effect on participation (Model 1: −65 %, Model 2: −64 %) compared with timber provision programmes. Fig. 5 visualizes participation effects of the explored positive agreements aims.

Contract partners: Trust and knowledge of the contract partners were frequently discussed in the collected literature as aspects affecting participation, yet the meta-regression did not return a significant result for the contract partner variable (Table 3).

Interactions between compensation and agreement aims: Annual payments showed a strong positive interaction with recreational service agreements, indicating a greater increase in participation compared to timber-focused agreements. In contrast, biodiversity and multifunctional agreements had significantly weaker interactions, meaning annual payment increases were less effective for these specific BES compared to timber provision programmes. For lump-sum payments, agreements targeting recreation, water, and forest multifunctionality showed stronger positive interaction effects on participation than timber-based agreements. However, lump-sum payments did not significantly differ in effectiveness for biodiversity or carbon sequestration agreements compared to timber provisioning (Interaction model in Appendix G).

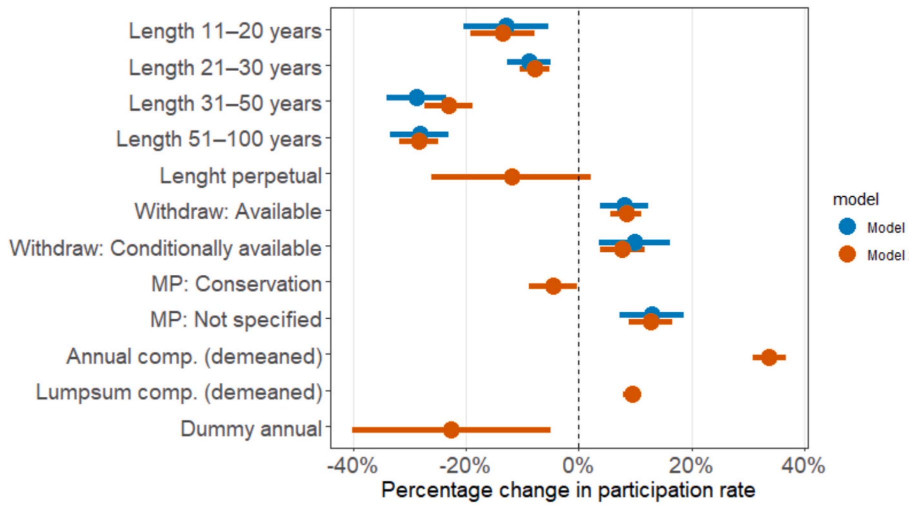

Fig. 4. Effects of contract design variables (p < 0.1) in the two meta-regression models. Circles represent the model coefficients corresponding to the contract design variables, and whiskers indicate the 95 % confidence intervals. MP: Management practice. **Reference levels:** Length; 1–10 year contracts, Withdraw; no contract withdrawal possible, Management practice (MP): Silvicultural management requirements.

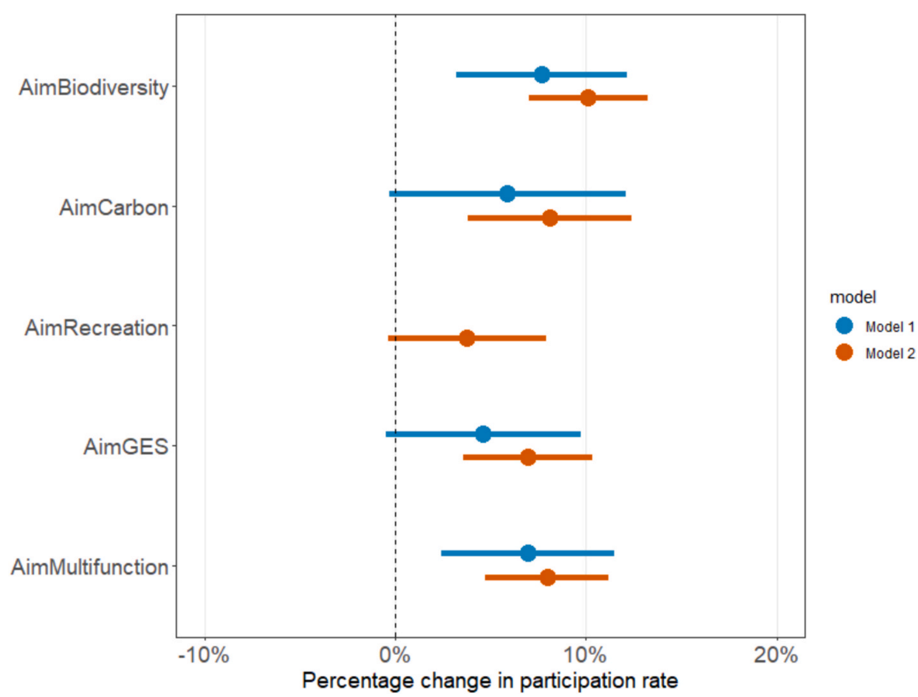

Fig. 5. Effects of agreement aim variables (p < 0.1) in two meta-regression models. Circles represent the model coefficients corresponding to the contract design variables, and whiskers indicate the 95 % confidence intervals. Reference level: Timber production agreements. GES: general ecosystem services; Multifunction: contracts combining two or more biodiversity or ecosystem services.

Temporal effects: Compared were programme aim preferences before 2013 (b2013) and starting from 2013 onwards (f2013) (Appendix H). The b2013 model showed no positive relations to programme aims in relation to timber production. Negatively significantly correlated were water and recreation agreements. The model including more recent survey results did show a significant and positive difference in participation estimations for biodiversity (17 %), carbon (16 %), GES (12 %) and multifunctional (20 %) programme aims compared to timber agreements.

4. Discussion

The challenge of proposing Europe-wide strategies to engage forest owners in voluntary forest management lies in the vast institutional differences and the heterogeneity of owner preferences. High between-cluster variances support the assumption of considerable differences between the datasets. Nonetheless, despite these differences, a handful of common participation preferences could be observed and are discussed below.

4.1. Methodological differences and control variables

Study methods and hypothetical agreements suggested to affect participation rate in the literature (Mitani & Lindhjem, 2022), as well as preliminary evaluations. However, these effects were not reproduced in the meta-regression, which may be due to the way the analyses were structured which already accounted for much of the variation in study-level differences. Consequently, any independent effect of these methodological factors may be too subtle to detect in this modelling framework. A further related finding was the non-significance of the timber price in the meta-regression. Contrary to other studies where a negative correlation was found between timber prices and participation in conservation programmes (Mitani & Lindhjem, 2022), the broadening of available contracts, which can possibly be monetized, may influence the effects of timber price fluctuation on participation.

4.2. Contract design

Increasing payments to incentivize the provision of common goods and ecosystem services internalizes the social values of these services and make participation economically more attractive (Engel et al., 2015). The meta-regression confirmed that both compensation types serve as a strong lever for participation, even though lump-sum payments were non-significant in the preliminary linear regression (Appendix B). The meta-regression results are in line with those from the review by Chizmar et al. (2024) on landowner perspectives on financial incentives, and with the reviewed literature (Mitani & Lindhjem, 2015; Vedel et al., 2015; Mäntymaa et al., 2018; Gołos et al., 2021; Tyrväinen et al., 2021). Overall, lump-sum payments were preferred over annual payments, which supports the argument that forest owners prefer to reduce uncertainty.

Restrictions set by voluntary management agreements are a common negative influence on participation rate (Fortney et al., 2011; Butler et al., 2012). This analysis confirmed prior research on forest owner preferences for shorter contracts, the availability of contract withdrawal options, and a case-specific preference for contracts where the management requirements are not specifically stated. Interestingly, the findings suggest that while the shortest contacts produce the highest participation rates, a switch from a 1–10-year contract to a 21–30-year contract was preferred over a stepwise increase to a 11-to-20-year contract. Nonetheless, short contract durations for BES agreements should be carefully considered, as there is evidence of path dependency, meaning the continuation of established management patterns, even after the contracts end (Lutter et al., 2019; Calle, 2020). The overall preference for contracts without management requirements, compared to silvicultural management requirements, supports the claim that restrictions reduce participation. The meta-regression analysis further suggested that agreements which require conservation measures produce lower participation rates over silvicultural management requirements if the compensation is accounted for (Model 2). The similar preference effects of contracts with conditionally available and fully available withdrawal options suggest that forest owners prefer agreements allowing them to decide whether to end the contract early. This finding supports those of Gołos et al. (2021) and Mäntymaa et al. (2018), who observed higher participation rates with weaker restrictions rather than no restrictions, and Huang et al. (2024), who found crowding-in effects for contract compliance measures.

4.3. Motivations and external influences

Focusing on the motivations of forest owners in Europe, both the meta-regression and the literature review provided supporting findings towards increased participation interest beyond economic benefits and timber production (Buckley et al., 2009; Mäntymaa et al., 2009; Boon et al., 2010; Follo et al., 2017; Ficko et al., 2019; Floress et al., 2019; Gołos et al., 2021; Wilkes-Allemann et al., 2021), suggesting a broader effect from environmental motivations (Mäntymaa et al., 2009, 2018; Mitani & Lindhjem, 2015).

Programme aims: In the meta-regression an overall higher participation rate was identified for agreements with biodiversity, carbon, GES and multifunctional BES aims compared with timber-production focused agreements.

In terms of required payments, previous research proposed that forest owners are willing to forgo compensation for biodiversity objectives and natural forest stands (Kline et al., 2000). Other studies have suggested that a positive view of environmental protection measures does not necessarily decrease the compensation requirements (Brouwer et al., 2015). Compared with timber-focused agreements, the meta-regression model does not support the statement of Kline et al. (2000). However, higher payments for the provision of certain BES appear to have positive interaction effects on participation in recreation-focused agreements, which suggests that agreements with recreation aims may require lower payments to achieve participation rates like those of timber-focused agreements. Overall, the preference for a certain payment schedule seems to be entangled with the programme aim and should be considered in the instrument design.

Contract partners: Trust in contract partners is considered key for increasing forest owner participation in voluntary management agreements (Kilgore et al., 2007; Lind-Riehl et al., 2015). However, identifying an overarching trust variable for a meta-regression of this scale was challenging. The summarizing variable ultimately applied was whether the identity or concrete institution of the contract partners was known to the forest owners. The preliminary analysis supported a positive association between participation rate and revealing the contract partners, but this effect was not confirmed in the meta-regression. Given the qualitative findings from the evaluated literature, contract partners seem to have influences on a more detailed level, with a variety of factors influencing the willingness of forest owners to participate and agree to management requirements (Abildtrup et al., 2021). Forest owners were most motivated to comply with family members, local forest managers, association advisors and forest centre advisors (Koskela & Karppinen, 2024). Tiebel et al. (2024) formed a similar list, with foresters, forestry associations and forest owner associations as the most influential actors. For programme partners, non-profit organizations were preferred over for-profit organizations and authorities (Kosenius, 2024), an effect further supported by locality. Regional contractors have been reported to be the preferred contract partner option of forest owners, over environmental organizations or government agencies (Pröbstl-Haider et al., 2020). However, a large number of owners for the same property has been found to decrease the participation rate in forest management agreements (Mäntymaa et al., 2018). In terms of compensation effects, technical advice was positively perceived and increased participation rates, as well as decreasing compensation demands (Brouwer et al., 2015). Finally, concerning the initiation of the contract, forest owners have been reported to prefer to initiate the contracts themselves (Horne, 2006).

Temporal shifts: Assessing the temporal dynamics of forest owner participation in European voluntary forest management agreements has become particularly interesting since the formation of European forest strategies and decisions by the European Commission on carbon accounting, which have created new market opportunities (European Commission, 2013; European Parliament and Council of the European Union, 2013). Descriptive results from this study showed sustained research interest in biodiversity programmes over time, while interest in multifunctionality and carbon sequestration programmes emerged only after 2012–2013. This trend aligns with the European Commission's increased focus on these forest provision areas. Timber-focused programmes were absent until 2009, which might be explained by the phrasing of the search string, which prioritized ecosystem service provisions and may have inadvertently excluded timber programmes not labelled as ecosystem provisions. In terms of forest owner participation, two temporal shifts were observed during the review. First, a generational shift occurred, with younger forest owners being more willing to participate in voluntary forest agreements (Mitani & Lindhjem, 2015; Nielsen et al., 2017, 2018). Second, there was an overall increase in interest in providing BES from forests beyond timber. While before 2013 no positive significant changes in participation over timber were measured, after 2013 participation in biodiversity, carbon, GES and multifunctional agreements all showed positive significant participation differences against the timber baseline. Such changes may influence forest provisions in the long term through path dependency, as familiarity with the programmes enhances the willingness to participate (Buckley et al., 2009; Nielsen et al., 2017). This trajectory further reflects a growing interest in the multifunctional role of forests, including climate change mitigation, as well as possible influences of the European forest strategy.

4.4. PES schemes in Europe

In addition to hypothetical programmes, several established or proposed PES schemes were identified and evaluated within the reviewed literature, providing practical insights into successful programme elements influencing forest owner participation. One interesting example is Finland's METSO programme. Operational since 2002, it has effectively adderssed biodiversity loss in southern Finland's forests by engaging forest owners through flexible, voluntary agreements ranging from short-term (10-year) to long-term and permanent contracts. METSO notably achieved its ambitious target of conserving 96,000 ha of forest ahead of schedule (Kangas and Ollikainen, 2025; METSO, 2025). Its approach to contract flexibility and the inclusion of relatively short temporary contracts may have supported the initial success of the programme. Similarly, Finland is exploring a landscape and recreational values trading scheme for targeted recreational ecosystem services, structuring compensation around income losses due to altered forest management aimed at increasing recreational values. However, a concrete implementation is still outstanding (Tyrväinen et al., 2021). In Denmark, a specialized PES scheme for conserving oak scrubs for biodiversity and cultural heritage, offered compensation scaled according to habitat quality, successfully engaging forest owners through targeted payments, offering another example of protecting cultural and recreational BES through PES (Nielsen et al., 2018). Ireland's afforestation programme employed direct financial incentives covering establishment costs and annual compensation for forgone agricultural income, resulting in private forest ownership reaching approximately 50 % of Ireland's forestry estate (O'Donnell et al., 2013; Duesberg & Dhubháin, 2019). Across these examples, flexible contract conditions, clear compensation linked to income foregone, and well-defined ecosystem service targets emerged as success factors.

While several biodiversity and conservation programmes are well established, further insights on actual forest owner participation in carbon sequestration agreements remain to be studied. Additional research could benefit from investigating these schemes sustained impacts, including their long-term ecological effectiveness, economic efficiency, and behavioural influences beyond contract periods. Additionally, evaluating voluntary agreement participation in relation to the biophysical characteristics of the forest could be a further important angle to which agreements can be structured, and should therefore be included in further research.

4.5. Limitations

This meta-regression synthesises two decades of European evidence on forest owner participation in voluntary forest-BES agreements. Despite identifying robust patterns, several limitations apply. First, agreement aims were categorized based on how each primary study framed them, rather than by specific forest practices. Consequently, identical management measures might fall under different labels across studies, potentially obscuring true preference signals. Second, unobserved heterogeneity in national and sub-national governance factors (e.g., cost-share programmes, tax incentives, or inspection regimes) could not be explicitly modelled. Including data from 12 different countries partially addresses this limitation, but finer-grained institutional data would strengthen policy effect isolation. Moreover, one agreement aim (water protection) was only studied in a single country, limiting cross-country comparisons for that aim. Third, the dataset mixes stated-preference choice experiments with revealed-preference adoption studies. Although we controlled for hypothetical bias using a dummy variable, residual differences might still inflate or distort estimated participation rates. Fourth, sampling strategies differed markedly across the primary studies. Reaching private forest owners usually relies on membership lists or association networks, which leads to clustering and selective non-response. These features inflate sampling variance, introduce selection bias, and violate the assumptions of simple random sampling. Where detailed sampling information becomes available, future meta-analyses could add study-level controls for sampling quality, although those controls may still be intertwined with country-specific governance structures. Fifth, biogeographic context, which may influence BES participation, was not explicitly analysed; future research should consider these ecological influences more systematically. Sixth, the review relied on English-language, peer-reviewed literature. Excluding grey literature and studies in other languages, which raises the possibility of language or publication bias. Finally, all moderator associations reported are correlational; without experimental variation in contract attributes, causal claims are not warranted. Consequently, extrapolation to new policy contexts, particularly in Southern and South-Eastern Europe, where data remains scarce, should be cautious. Targeted primary research in these underrepresented regions, employing designs capturing actual behaviours, would substantially strengthen future analyses.

5. Concluding remarks

The engagement of non-industrial private forest owners is becoming increasingly important for policymakers striving to meet the rising demand for forest-based ecosystem services, ranging from climate change mitigation to recreation. While national preferences for forest provisions vary across Europe, the findings from this study suggest that forest owners share a disposition to participate in voluntary BES agreements and support multifunctional forests. Short-term contracts with minimal restrictions can serve as an effective gateway, creating a path dependency that fosters increased provision of BES in the long run. Low fixed restrictions coupled with accountability clauses help build trust in these arrangements, encouraging potential future engagement. Additionally, forest owners' growing and diverse interests, beyond timber production, present an opportunity to better tailor agreements and incentives, thereby reaching a wider range of forest owners interested in providing a multifunctional landscape of BES.

Looking ahead, it will be crucial to understand the drivers behind long-term engagement beyond fixed contract terms. Future research should examine the role of key actors, the specific incentives most likely to increase participation, and how path dependency can be strategically cultivated within voluntary agreements. Strengthening these insights will ultimately enable policymakers and forest managers to build on the experiences of current programmes to design more adaptive, attractive, and impactful policy tools that align with both national differences and shared preferences across European forest owners.

CRediT authorship contribution statement

Samuel U. Ringier: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Yohei Mitani:** Writing – review & editing, Validation, Resources, Methodology, Conceptualization. **Janine Schweier:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Henrik Lindhjem:** Writing – review & editing, Resources, Methodology, Funding acquisition, 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.

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Appendix

Appendix A. Table summarizing the literature included in the study

paper id	data id	authors	year	journal	mean PR[1]	mean SE	n_obs[3]	country	survey year	comp_min[4]	comp_max[4]	Payment	Aims	Partner	MP[5]
1	1	Juutinen et al.	2021	FPE	0.867	0.03	30	Finland	2020	400	2000	Lump sum	Timber, Biodiversity, Carbon, GES Multifunction	1	Silviculture
2	2	Juutinen et al.	2022	FPE	0.746	0.051	30	Austria	2020	400	2000	Lump sum	Timber, Biodiversity, Carbon, GES Multifunction	1	Silviculture, NS[6]
2	3	Juutinen et al.	2022	FPE	0.791	0.054	30	Germany	2020	400	2000	Lump sum	Timber, Biodiversity, Carbon, GES Multifunction	1	Silviculture, Conservation
2	4	Juutinen et al.	2022	FPE	0.689	0.069	30	Slovenia	2020	400	2000	Lump sum	Timber, Biodiversity, Carbon, GES Multifunction	1	Silviculture, NS[6]
2	5	Juutinen et al.	2022	FPE	0.687	0.058	30	Sweden	2020	400	2000	Lump sum	Timber, Biodiversity, Carbon, GES Multifunction	1	Silviculture, NS[6]
3	6	Tiebel et al.	2024	People and Nature	0.333	0.011	3	Germany	2020	NA	NA	NA	Timber, GES, Multifunction	0	NS[6]
4	7	Abildtrup et al.	2021	Forests	0.588	0.102	5	France	2015	25	125	Annual	Biodiversity	1	NS[6]
5	8	Golos et al.	2021	Forests	0.5	0.016	2	Poland	2019	233	633	Annual	Biodiversity	0	Conservation, NS[6]
6	9	Koskela et al.	2021	SCF	0.15	0.011	4	Finland	2015	0	0	Lump sum	Biodiversity	0	Conservation
7	10	Santos et al.	2021	Forests	0.489	0.032	12	Portugal	2018	20	500	Annual	GES	1	Silviculture
8	11	Tyrväinen et al.	2021	LUP	0.235	0.092	42	Finland	2012	0	300	Annual	Recreation	0	Conservation, NS[6]
9	12	Pröbstl-Haider	2020	FPE	0.452	0.015	2	Austria	2015	1000	1000	Lump sum	GES	1	Silviculture, NS[6]
10	13	Vidyaratnea	2020	LUP	0.628	0.027	1	Ireland	2011	430	430	Annual	Timber	0	Silviculture
11	14	Boon et al.	2010	SJFR	0.357	0.012	1	Denmark	2002	0	0	Lump sum	GES	0	Conservation
12	15	Broch et al.	2012	EE	0.732	0.059	54	Denmark	2009	3600	5600	Lump sum	Biodiversity, Recreation, Water	0	Silviculture
13	16	Buckley	2009	JEPM	0.49	0.016	1	Ireland	2007	NA	NA	NA	Recreation	0	NS[6]
14	17	Horne	2006	SF	0.607	0.046	96	Finland	2003	0	350	Annual	Biodiversity	1	Conservation, NS[6]
15	18	HÎbesland et al.	2016	FPE	0.514	0.254	12	Norway	2013	6.41	76.9	Annual	Carbon	0	NS[6]
16	19	Layton & Siikamäki	2009	ERE	0.056	0.007	1	Finland	2000	NA	NA	NA	Biodiversity	1	Conservation
17	20	Mitani and Lindhjem	2015	LE	0.43	0.02	1	Norway	2008	0	0	Lump sum	Biodiversity	0	Conservation
18	21	Mantymaa et al	2009	FPE	0.63	0.051	1	Finland	2004	205	205	Lump sum	Biodiversity	1	Conservation
19	22	Vedel et al.	2015	EE	0.057	0.01	32	Denmark	2012	0	23.5	Annual	Biodiversity, Recreation, GES, Multifunction	0	Conservation
20	23	Brouwer	2015	JFE	0.559	0.111	72	Netherlands	2012	250	2000	Annual	Timber, Biodiversity, Multifunction	0	Silviculture
20	24	Brouwer	2015	JFE	0.381	0.116	72	Germany	2012	250	2000	Annual	Timber, Biodiversity, Multifunction	0	Silviculture
21	25	Nielsen et al.	2018	JFE	0.507	0.018	1	Denmark	2008	NA	NA	NA	Biodiversity	1	NS[6]
22	26	Nielsen et al.	2017	CB	0.002	0.003	1	Denmark	2008	NA	NA	NA	Biodiversity	1	Conservation
23	27	Mantymaa et al.	2018	JFE	0.43	0.023	1	Finland	2017	NA	NA	NA	GES	1	Conservation
24	28	Kosenius	2024	SCF	0.511	0.03	4	Finland	2019	210	310	Annual	Multifunction	0	Conservation

[1]PR: Participation rate, [2]SE: Standard error, [3]Number of observation produced from the dataset, [4]Compensation in EUR, as reported in the primary data source, [5]Aims per agreement, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services, [6]Management practice, [7]Not specified, NA: Not applicable.

Appendix B. Significant differences in relation to participation rate

variable	test	Column1	statistic	p.value
Contract_length	ANOVA	F-value	18.48	0.00
MP[a]	ANOVA	F-value	39.889	0.00
Aim	ANOVA	F-value	10.54	0.00
Withdraw	ANOVA	F-value	13.154	0.00
Study_method	ANOVA	F-value	4.358	0.013
Partner_known	t.test	t-value	−12.035	0.00
SE_Dummy[b]	t.test	t-value	11.69	0.00
Hypothetical	t.test	t-value	−4.233	0.00
Dannual[c]	t.test	t-value	14.957	0.00
Comp_annual	OLS	estimate (R2)	0.0001654 (0.15)	0.00
Comp_lumsum	OLS	estimate (R2)	0.00001365 (0.18)	0.14
Timber_price[d]	OLS	estimate (R2)	−0.30769 (0.05)	0.00

[a]Management practice,
[b]standard error estimation dummy,
[c]payment schedule dummy for annual payments,
[d]yearly and nationally adjusted timber price.

Appendix C. Summary of categorical and continuous variables for Model 1 and Model 2

Variable	Category	Model 1 Proportion	SD[1]	Model 2 Proportion	SD[1]
Categorical variables					
Aim	Biodiversity	36 %	0.48	36 %	0.48
Aim	Carbon	7 %	0.26	8 %	0.26
Aim	GES	10 %	0.30	9 %	0.29
Aim	Multifunctional	20 %	0.40	20 %	0.40
Aim	Recreation	12 %	0.33	12 %	0.33
Aim	Timber	12 %	0.32	12 %	0.32
Aim	Water	3.2 %	0.17	3.2 %	0.18
Contract duration	1–10	25 %	0.43	25 %	0.43
Contract duration	11–20	30 %	0.46	31 %	0.46
Contract duration	21–30	14 %	0.34	14 %	0.35
Contract duration	31–50	10 %	0.30	10 %	0.30
Contract duration	51–100	4 %	0.20	4 %	0.20
Contract duration	NS[7]	1 %	0.08	–	–
Contract duration	Perpetual	16 %	0.37	16 %	0.37
Dannual[2]	0	–	–	38 %	0.48
Dannual[2]	1	–	–	62 %	0.48
Hypothetical	No	24 %	0.43	–	–
Hypothetical	Yes	76 %	0.43	–	–
Partner no[3]	0	53 %	0.50	53 %	0.50
Partner yes[3]	1	47 %	0.50	47 %	0.50
Withdraw	Av[8]	10 %	0.29	10 %	0.29
Withdraw	CondAv[8]	6 %	0.24	6 %	0.25
Withdraw	NS[7]	70 %	0.46	69 %	0.46
Withdraw	NotAv[8]	15 %	0.35	15 %	0.36
Management practice	Conservation	25 %	0.43	24 %	0.43
Management practice	NS[7]	27 %	0.44	26 %	0.44
Management practice	Silviculture	49 %	0.50	50 %	0.50
SE Dummy[4]	0	89 %	0.32	90 %	0.29
SE Dummy[4]	1	11 %	0.32	10 %	0.29
Study method	CE[9]	95 %	0.22	–	–
Study method	DC[9]	4.2 %	0.20	–	–
Study method	Other	1.1 %	0.10	–	–
Continuous variables					
Mean compensation annual[5]		–	–	293.98	501.86
Mean compensation lump-sum[5]		–	–	742.80	1310.69
Mean timber price[6]		88.38	20.22	88.59	20.31
Mean participation rate		0.55	0.27	0.56	0.27

[1]SD = standard deviation;
[2]Dummy variable for annual payments;
[3]Dummy variable if the identity of contract partners is known;
[4]Dummy variable for standard error (SE) estimation method 1 = proportional estimation
[5]Inflation adjusted compensation EUR/ha, mean including 0 values from payments made as lump-sum or annual payments, accounted for with an annual payment dummy variable;
[6]Inflation- and country-adjusted yearly demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough);
[7]Not specified;

[8]Av: Available, CondAv: Conditionally available, NotAv: not available.
[9]CE: choice experiment, DC: dichotomous choice survey.

Appendix D. Logit transformed regression results

Regression coefficients for three level mate regression Model 1 and Model 2

Variable	Model 1 Estimate		SE	t-value	CI.lb	CI.ub	Model 2 Estimate		SE	t-value	CI.lb	CI.ub
MethodDC[a]	0.0058		0.8533	0.0068	−1.6704	1.6819	–		–	–	–	–
MethodOther[a]	1.1216		0.9572	1.1717	−0.7587	3.002	–		–	–	–	–
Hypothetical_Yes[b]	0.8814		0.7006	1.2581	−0.4948	2.2575	–		–	–	–	–
SE_Dummy1[c]	−1.0957		0.7253	−1.5108	−2.5204	0.3289	−0.7365		0.45	−1.641	−1.62	0.145
Contract11-20[d]	−0.8762	***	0.2579	−3.397	−1.3828	−0.3695	−0.9788	***	0.23	−4.307	−1.43	−0.53
Contract21-30[d]	−0.3895	***	0.1016	−3.8326	−0.5892	−0.1899	−0.382	***	0.08	−4.757	−0.54	−0.22
Contract31-50[d]	−0.9855	***	0.1464	−6.7329	−1.273	−0.698	−1.0395	***	0.13	−8.272	−1.29	−0.79
Contract51-100[d]	−1.2518	***	0.1376	−9.0962	−1.5221	−0.9815	−1.2487	***	0.1	−12.11	−1.45	−1.05
ContractPerpetual[d]	−0.7882		0.5015	−1.5717	−1.7732	0.1969	−0.8637	.	0.47	−1.846	−1.78	0.056
ContractNS[d]	−1.5697		1.2116	−1.2956	−3.9497	0.8102	–		–	–	–	–
WithdrawAV[e]	0.3855	***	0.1151	3.3482	0.1593	0.6117	0.3979	***	0.09	4.6284	0.229	0.567
WithdrawCondAv[e]	1.1872	***	0.2392	4.9631	0.7174	1.6571	1.1835	***	0.21	5.7502	0.779	1.588
WithdrawNS[e]	−0.4315		0.7243	−0.5957	−1.8543	0.9914	−0.6421		0.53	−1.219	−1.68	0.393
MPConservation[f]	−0.2719		0.1732	−1.57	−0.6121	0.0683	−0.2549	.	0.13	−1.907	−0.52	0.008
MPNS[f]	0.5672	***	0.1571	3.6107	0.2586	0.8757	0.5856	***	0.12	4.7994	0.346	0.825
AimBiodiversity[g]	0.4921	***	0.124	3.969	0.2485	0.7356	0.5396	***	0.1	5.3896	0.343	0.736
AimCarbon[g]	0.3381	.	0.177	1.9104	−0.0095	0.6858	0.4096	**	0.14	2.8629	0.129	0.691
AimRecreation[g]	−1.0555	***	0.2596	−4.0667	−1.5654	−0.5457	−0.98	***	0.22	−4.394	−1.42	−0.54
AimWater[g]	−4.1246	***	0.3043	−13.5532	−4.7224	−3.5268	−4.1268	***	0.27	−15.44	−4.65	−3.6
AimGES[g]	0.2842	*	0.1419	2.0022	0.0054	0.563	0.3261	**	0.11	2.9375	0.108	0.544
AimMultifunction[g]	0.3097	*	0.128	2.4202	0.0583	0.561	0.3487	**	0.11	3.2312	0.137	0.561
Partner_Yes[h]	0.0711		0.5115	0.1389	−0.9338	1.0759	0.0964		0.48	0.1988	−0.86	1.049
Timber_price[i]	0.2986		1.5699	0.1902	−2.7852	3.3825	1.4842		1.15	1.2947	−0.77	3.736
Comp_annual[j]	–	–	–	–	–	–	1.4335	***	0.1	14.719	1.242	1.625
Comp_lump-sum[j]	–	–	–	–	–	–	0.6712	***	0.06	10.602	0.547	0.796
Dannual1[k]	–	–	–	–	–	–	−1.0353	*	0.47	−2.183	−1.97	−0.1
Intercept	0.2976		0.8224	0.3619	−1.3178	1.913	1.9393	*	0.77	2.5238	0.43	3.449
Loglik	−655.5172						−498.4077					
Deviance	1311.0345						996.8154					
AIC	1363.0345						1046.8154					
BIC	1474.9501						1154.0119					
AICc	1365.7345						1049.3545					
I^2 Level 2	16.59 %						15.99 %					
I^2 Level 3	81.56 %						79.88 %					
I^2 Total	98.15 %						95.87 %					

Significance: *** $p < 0.001$, ** $p < 0.01$, * p < 0.5,. $p < 0.1$.

[a]Method: Data collection method, baseline: choice experiment, DC: dichotomous choice; [b]Dummy variable for hypothetical agreements; [c]Dummy variable for standard error (SE) estimation method 1 = proportional estimation; [d] Contract duration, baseline: 0–10 years, Perpetual = contract with no time limit, NS = not specified; [e]Options to withdraw from contract, baseline: no option to withdraw, AV = available, CondAV = conditionally available, NS = not specified; [f]Management practice, baseline: silvicultural management, NS = not specified; [g]Contract aim, baseline: timber production, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services; [h]Dummy variable if identity of contract partner is known; [i]Inflation- and country-adjusted demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough) (1 unit = 100EUR) (UNECE, 2021; Eurostat, 2024a); [j]Demeaned and inflation-adjusted (Eurostat, 2024a) compensation in EUR/ha (1 unit = 1000EUR); [k]Dummy variable for annual payments. SE = standard error. CI: 95 % confidence interval with lower and upper bounds.

Appendix E. VIF evaluation of regression moderators to evaluate collinearity

variable	VIF_Model1	VIF_Model2
AimBiodiversity	2.659	2.919
AimCarbon	1.793	1.759
AimGES[a]	1.868	2.017
AimMultifunction[a]	2.209	2.286
AimRecreation	1.853	2.103
AimWater	1.44	1.463
Contract11-20	1.183	1.187
Contract21-30	1.189	1.166
Contract31-50	1.131	1.133
Contract51-100	1.062	1.072
ContractNS[b]	1.765	NA
ContractPerpetual[b]	1.741	1.671
Dannual1[c]	NA	1.719
Hypothetical_Yes	1.906	NA
MPConservation[d]	3.353	3.417
MPNS[d]	3.586	3.702

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variable	VIF_Model1	VIF_Model2
Partner_Yes[e]	1.224	1.757
SE_Dummy1[f]	2.569	1.409
MethodDC[g]	2.944	NA
MethodOther[g]	2.032	NA
WithdrawAV[h]	1.01	1.008
WithdrawCondAv[h]	1.011	1.024
WithdrawNS[h]	1.866	1.874
Comp_annual[i]	NA	1.041
Comp_lump-sum[i]	NA	1.077
Timber_price[j]	2.308	2.174

[a]Contract aim, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services; [b] Contract duration, Perpetual = contract with no time limit, NS = not specified; [c]Dummy variable for annual payments; [d]Management practice, NS = not specified; [e]Dummy variable if identity of contract partner is known; [f]Dummy variable for standard error (SE) estimation method 1 = proportional estimation; [g]Method: Data collection method, DC: dichotomous choice; [h]Options to withdraw from contract, AV = available, CondAV = conditionally available, NS = not specified; [i]Demeaned and inflation-adjusted (Eurostat, 2024a); [j]Inflation- and country-adjusted demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough) (1 unit = 100EUR) (UNECE, 2021; Eurostat, 2024a).

Appendix F. Robustness analysis: Significant effect results from the regressions

Variable	Model 2			
	OLS	**GLS**	**Tobit**	**Meta-reg**
Intercept	+	+	+	+
SE_Dummy1[a]	NS	NS	NS	NS
Contract11-20[b]	−	−	−	−
Contract21-30[b]	−	−	−	−
Contract31-50[b]	−	−	−	−
Contract51-100[b]	−	−	−	−
ContractPerpetual[b]	−	−	−	(−)
WithdrawAV[c]	+	+	+	+
WithdrawCondAv[c]	+	+	+	+
WithdrawNS[c]	NS	NS	NS	NS
MPConservation[d]	−	−	−	NS
MPNS[d]	+	+	+	+
AimBiodiversity[e]	+	+	+	+
AimCarbon[e]	+	+	+	+
AimRecreation[e]	(−)	NS	NS	(+)
AimWater[e]	−	−	−	−
AimGES[e]	NS	NS	NS	+
AimMultifunction[e]	+	+	+	+
Partner_Yes[f]	+	+	+	NS
Timber_price[g]	−	−	−	NS
Comp_annual[h]	+	+	+	+
Comp_lump-sum[h]	+	+	+	+
Dannual1[i]	−	−	−	−

Significance and effect: positive effect +, negative effect −, significant ($p < 0.05$), in brackets (+)($p < 0.1$).

[a]Dummy variable for standard error (SE) estimation method 1 = proportional estimation; [b] Contract duration, baseline: 0–10 years, Perpetual = contract with no time limit, NS = not specified; [c]Options to withdraw from contract, baseline: no option to withdraw, AV = available, CondAV = conditionally available, NS = not specified; [d]Management practice, baseline: silvicultural management, NS = not specified; [e]Contract aim, baseline: timber production, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services; [f]Dummy variable if identity of contract partner is known; [g]Inflation- and country-adjusted demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough) (1 unit = 100EUR) (UNECE, 2021; Eurostat, 2024a); [h]Demeaned and inflation-adjusted (Eurostat, 2024a) compensation in EUR/ha (1 unit = 1000EUR); [i]Dummy variable for annual payments. NS = not significant.

Appendix G. Interaction model between agreement aims and annual / lump-sum compensation

Interaction terms highlighted in green.

	estimate	std.error	p.value	conf.low	conf.high
Intercept	0.799	0.154	0.000	0.497	1.100
SE_Dummy1[a]	−0.070	0.103	0.497	−0.272	0.132
Contract11-20[b]	−0.128	0.027	0.000	−0.180	−0.075
Contract21-30[b]	−0.079	0.012	0.000	−0.103	−0.054
Contract31-50[b]	−0.231	0.021	0.000	−0.271	−0.190
Contract51-100[b]	−0.287	0.015	0.000	−0.317	−0.257

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	estimate	std.error	p.value	conf.low	conf.high
ContractPerpetual[b]	−0.120	0.062	0.053	−0.243	0.002
WithdrawAV[c]	0.084	0.013	0.000	0.059	0.109
WithdrawCondAv[c]	0.065	0.017	0.000	0.032	0.099
WithdrawNS[c]	−0.172	0.113	0.128	−0.394	0.050
MPConservation[d]	−0.123	0.023	0.000	−0.169	−0.078
MPNS[d]	0.050	0.022	0.025	0.006	0.093
Partner_Yes[e]	0.135	0.106	0.206	−0.074	0.344
Timber_price[f]	0.302	0.226	0.181	−0.141	0.746
AimBiodiversity[g]	0.139	0.015	0.000	0.109	0.169
AimCarbon[g]	1.270	0.756	0.092	−0.210	2.760
AimMultifunction[g]	0.126	0.016	0.000	0.094	0.158
AimRecreation[g]	0.243	0.051	0.000	0.143	0.342
AimWater[g]	−1.400	0.129	0.000	−1.650	−1.150
Comp_annual[h]	0.392	0.024	0.000	0.345	0.439
Comp_lump-sum[h]	0.066	0.014	0.000	0.039	0.094
Dannual1[i]	−0.203	0.100	0.043	−0.400	−0.006
AimBiodiversity:Comp_annual[j]	−0.093	0.027	0.001	−0.146	−0.041
AimCarbon:Comp_annual[j]	3.800	2.570	0.140	−1.260	8.850
AimMultifunction:Comp_annual[j]	−0.076	0.027	0.005	−0.129	−0.023
AimRecreation:Comp_annual[j]	0.573	0.162	0.000	0.255	0.891
AimBiodiversity:Comp_lump-sum[j]	0.016	0.017	0.336	−0.017	0.050
AimCarbon:Comp_lump-sum[j]	−0.003	0.028	0.927	−0.057	0.052
AimMultifunction:Comp_lump-sum[j]	0.065	0.021	0.002	0.025	0.105
AimRecreation:Comp_lump-sum[j]	0.032	0.017	0.057	−0.001	0.066
AimWater:Comp_lump-sum[j]	0.292	0.043	0.000	0.207	0.377

[a]Dummy variable for standard error (SE) estimation method 1 = proportional estimation; [b] Contract duration, baseline: 0–10 years, Perpetual = contract with no time limit; [c]Options to withdraw from contract, baseline: no option to withdraw, AV = available, CondAV = conditionally available, NS = not specified; [d]Management practice, baseline: silvicultural management, NS = not specified; [e]Dummy variable if identity of contract partner is known; [f]Inflation- and country-adjusted demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough) (1 unit = 100EUR) (UNECE, 2021; Eurostat, 2024a); [g]Contract aim, baseline: timber production, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services; [h]Demeaned and inflation-adjusted (Eurostat, 2024a) compensation in EUR/ha (1 unit = 1000EUR); [i]Dummy variable for annual payments. NS = not significant; [j]aim-compensation interaction terms. Confidence interval 95 %.

Appendix H. Regression results temporal analysis of the two models with observations from 2013 and from 2013 onward

	Model b2013 (10 Datasets, 372 Observations)			Model f2013 (12 Datasets, 189 Observations)		
Term	**Estimate**		**SE**	**Estimate**		**SE**
Intercept	0.8445	***	0.1431	0.2739		0.1939
SE_Dummy1[a]	−0.2725		0.2381	−0.2435	***	0.0641
Contract11-20[b]	−0.1446	***	0.0282	−0.027		0.1369
Contract21-30[b]	−0.0751	***	0.0129	0.0057		0.1132
Contract31-50[b]	−0.2485	***	0.0223	−0.0472		0.1082
Contract51-100[b]	−0.2807	***	0.016	–	–	–
ContractPerpetual[b]	0.2817		0.2624	−0.0363		0.1326
WithdrawAV[c]	0.0842	***	0.013	−0.237		0.1586
WithdrawCondAv[c]	0.0719	***	0.0177	–	–	–
WithdrawNS[c]	−0.1451		0.1519	0.1431		0.1001
MPConservation[d]	−0.0622		0.1092	−0.02		0.0295
MPNS[d]	0.1399		0.1092	0.0233		0.0209
AimBiodiversity[e]	0.0164		0.0232	0.1746	***	0.0193
AimCarbon[e]	–	–	–	0.1557	***	0.0221
AimRecreation[e]	−0.0468	.	0.0258	–	–	–
AimWater[e]	−0.7169	***	0.0345	–	–	–
AimGES[e]	0.0147		0.0295	0.1162	***	0.0187
AimMultifunction[e]	−0.0287		0.0226	0.2034	***	0.0221
Partner_Yes[f]	0.3722		0.2492	0.417	***	0.0943
Timber_price[g]	1.0566	*	0.4888	−0.3896		0.2533
Comp_annual[h]	0.327	***	0.0148	0.6379	***	0.0714
Comp_lump-sum[h]	0.1262	***	0.0136	0.0724	***	0.0094
Dannual1[i]	−0.4048	*	0.1985	0.0825		0.1065
Loglik	370.5013			231.7596		
Deviance	−741.003			−463.519		
AIC	−693.003			−421.519		
BIC	−600.412			−355.667		
AICc	−689.31			−415.276		

Significance: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.5$,. $p < 0.1$.

[a]Dummy variable for standard error (SE) estimation method 1 = proportional estimation; [b] Contract duration, baseline: 0–10 years, Perpetual = contract with no time limit, NS = not specified; [c]Options to withdraw from contract, baseline: no option to withdraw, AV = available, CondAV = conditionally available, NS = not specified; [d]Management practice, baseline: silvicultural management, NS = not specified; [e]Contract aim, baseline:

timber production, GES = general ecosystem services, Multifunction = contracts combining two or more biodiversity or ecosystem services; [f]Dummy variable if identity of contract partner is known; [g]Inflation- and country-adjusted demeaned timber price in USD, per m^3 or per mt of roundwood (in the rough) (1 unit = 100EUR) (UNECE, 2021; Eurostat, 2024a); [h]Demeaned and inflation-adjusted (Eurostat, 2024a) compensation in EUR/ha (1 unit = 1000EUR); [i]Dummy variable for annual payments.

Data availability

Dataset of coded literature is available at the European open data repository https://zenodo.org/records/17086968.

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