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Understanding Forest Owners' Behaviors Toward Natural Insurance in Europe

Fanny Claise [*], Marielle Brunette [†], Rasoul Yousefpour [‡]

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Abstract

Natural insurance, which is based on the provision of ecosystem services, could strengthen forest resilience and reduce vulnerability to natural disturbances. However, little is known about how forest owners behave with regard to providing this forest function. To address this knowledge gap, this study surveyed private forest owners in four European countries, analysisng their behaviors towards natural insurance. Our multi-step approach uses descriptive statistics, cluster and principal component analyses and logit regressions. Our results reveal significant cross-country differences in terms of natural insurance behaviors. Four profiles of private forest owners were identified: incentive-sensitive, proactive managers, disengaged, and highly engaged. The provision of natural insurance is primarily influenced by the socio-economic characteristics of owners and the attributes of their forest properties, while management practices vary depending on the practice and the country considered.

Keywords: Forest; Natural Insurance; Behavioral typology; Logit
JEL Codes: Q23 (Forestry and Forest Management), Q54 (Climate and Natural Disasters), Q57 (Ecosystem Services and Biodiversity)

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1 Introduction

Forests provide a wide range of ecosystem services that extend far beyond timber production, including climate regulation, biodiversity conservation, and water cycle maintenance. Among these services, the role of forests as a form of *natural insurance* has recently gained increasing attention in both scientific and policy debates. Natural insurance refers to the capacity of ecosystems to reduce the likelihood and severity of natural hazards such as floods, avalanches, soil erosion, or water quality degradation. By stabilizing ecological processes and buffering environmental shocks, forests contribute to the resilience of socio-ecological systems (Unterberger and Olschewski, 2021).

In the context of climate change and the increasing frequency of extreme events, this protective function is more and more recognized as a key component of nature-based solutions (NbS). Forest-based solutions (FbS), in particular, can be understood as a subset of NbS in which forests simultaneously support human well-being and biodiversity conservation (Rey et al., 2024). Beyond their direct ecological benefits, forests can thus be seen as providers of a form of "insurance value" to society, reducing exposure to environmental risks while enhancing system resilience. In particular, ecosystem services help reduce variations in production and income for ecosystem managers (e.g., forest owners) as well as for other beneficiaries of these services (e.g., residents living near forests, the society as a whole). The European Commission highlights the benefits for the economy, describing NbS as facilitators in the transition to a more resource-efficient economy and towards sustainable economic growth (Bauduceau et al., 2015). In addition, the Commission highlights the need to "assess the insurance value of nature" and "integrate it into the disaster risk management agenda".

The theoretical foundations of the concept of natural insurance originate from the work of Baumgärtner (2007), who formalized the idea that biodiversity can act as an insurance mechanism in ecosystem service provision. In this framework, biodiversity reduces the risk of under- or over-provision of ecosystem services in the presence of environmental uncertainty. Few years later, Baumgärtner and Strunz (2014) showed that the higher an ecosystem's capacity to regulate and withstand adverse effects, such as natural hazards, the higher its insurance value. This concept has since been extended to account for endogenous risk, ecosystem resilience, and the value of natural capital (Baumgärtner and Strunz, 2014; Quaas et al., 2019; Quaas and Baumgärtner, 2008). More recent contributions have further explored its economic valuation (Augeraud-Véron et al., 2019; Faure and Mouysset, 2025) and its implications for agricultural and forest systems.

In order to operationalise the natural insurance function of forests, it seems essential to have information about the supply and demand for regulating ecosystem services. To our knowledge, research on the demand side is very recent. Unterberger and Olschewski (2021) were the first to quantify the benefits of forest-based risk reduction from the beneficiaries' perspective. Using a discrete choice experiment, they demonstrate that households in mountainous regions of Switzerland are willing to pay for forest management practices that enhance protective functions. Research on the supply of regulating ecosystem services is more established and has provided estimates that improve our understanding of the insurance services provided by ecosystems. For instance, Beck et al. (2018) demonstrated that coral reefs play a vital role in safeguarding coastal areas against storms and flooding. They found that, without coral reefs, the expected annual global damage caused by flooding would more than double, and the economic costs associated with frequent storms would increase threefold. Similarly, Strand et al. (2018) provided estimates for the four main ecosystem services provided by the Brazilian Amazon forest: between approximately USD 60 and USD 740 per hectare per year. While these studies focus on the supply of the natural insurance function, they never question the main providers of this function: forest owners. This is a particularly relevant issue in Europe, where a large proportion of forests are privately owned. The provision of natural insurance services depends critically on individual management decisions, which are shaped by heterogeneous perceptions, economic incentives, and institutional contexts. Although the protective functions of forests are increasingly recognised in ecological and policy discussions, it remains unclear whether private forests provide natural insurance and whether forest owners would encourage this function and, if so, under what conditions. A better understanding of how private forest owners' behave in relation to the natural insurance function of their forests seems to be a prerequisite for developing this function.

This is precisely the objective of this paper. To our knowledge, we provide the first large-scale empirical analysis of private forest owners' behavior regarding the natural insurance function of forests. Using a harmonised survey conducted in four European countries (Finland, France, Germany, and Spain), we analyze (i) whether forest owners think their forests currently provide natural insurance, (ii) whether they are willing to promote this function in the future, (iii) whether they already receive or expect to receive financial compensation for doing so, and (iv) which management practices they associate with improved natural insurance functions. Methodologically, we propose an original approach combining descriptive statistics, behavioral clustering, and econometric modeling. First, using descriptive statistics, we summarize the forest owners' behavior towards natural insurance provision: current provision, willingness to promote the provision in the future, current and expected compensation, and the management

practices favoring the function. Our result indicate significant cross-country differences in terms of natural insurance behaviors. Second, a multivariate analysis combining Principal Component Analysis (PCA) and cluster analysis is implemented to identify behavioral typologies among forest owners. This approach allows to identify four private forest owners' profile in terms of natural insurance: incentive-sensitive, proactive managers, disengaged and highly engaged. Third, we estimate regression models to identify potential determinants of the current provision of natural insurance and the preferred management practices. The results reveal that the provision of natural insurance is significantly explain both by the characteristics of the forest owner (income, education, children) and the characteristics of the forest property (certification, experience hazards, insurance). For the management practices, we obtain that the determinants are practice-and country dependent.

By providing new empirical evidence on the behavioral and economic drivers of forest management decisions, this paper contributes to the literature on ecosystem services and nature-based solutions. It also offers policy-relevant insights for the design of instruments aimed at aligning private incentives with public risk mitigation objectives, thereby supporting more resilient socio-ecological systems.

The remainder of the paper is organized as follows. Section 2 presents the material and method. Section 3 reports the empirical results. Section 5 concludes and discusses policy implications and avenues for future research.

2 Material and method

2.1 Survey design and data collection

To empirically investigate forest owners' situation regarding the natural insurance function of forests, a structured questionnaire was developed and distributed across four European countries: Finland, France, Germany and Spain. These countries were selected to ensure a high degree of heterogeneity in forest ownership structures, ecological conditions, and institutional frameworks governing forest management. Together, they provide a relevant contrast between Nordic, Central European, and Southern European forest systems. In these countries, traditional financial insurance already exist to protect against fire and/or storm. This means that the population of private forest owners is already familiar with the notion of insurance, facilitating the understanding of the questions related to "natural insurance", a

concept that is still emerging. The survey targeted private forest owners and was administered through national forest owner associations and a survey company in 2024.[1] The final database contains 1,047 respondents, distributed as follows: 247 in Finland, 360 in France, 250 in Germany, and 192 in Spain. This combination of a cross-country element and a large sample size is unusual. Indeed, such a sample remains rare in forestry literature, regardless of the research question. However, there are some exceptions, such as Feliciano et al. (2017), who examined how private forest owners in Europe conceptualise forest management using a sample of 1,140 respondents from seven European countries, and Wiersum et al. (2005), who investigated how forest owners perceive their own forests using a survey of 1,401 small-scale forest owners from eight European countries. Regarding the natural insurance function of forests in Europe, our sample remains original.

The questionnaire is composed of five sections (see Figure 1 in Claise and Brunette (2025a)): forests characteristics (species, location, area, etc.), Discrete Choice Experiment on financial insurance, elicitation of risk preferences (Multiple Price List methodology of Eckel and Grossman (2008)), past experience with natural hazards and forest insurance, and socio-demographic characteristics (gender, age, income, etc.). Questions related to natural insurance were part of section 4 about their experience with insurance. We used data from sections 1, 3, 4 and 5 of the questionnaire in this article. Data from section 2 were used for France in Claise and Brunette (2025a).

2.2 Natural insurance questions

Firstly, we explained the notion of "natural insurance" to the respondents: *"Natural insurance protects against the consequences of natural hazards. It provides protection against natural hazards for exposed populations. In other words, it's not the forest that's insured here, but the forest that serves as insurance for others. In mountainous areas, for example, forests play an important role in protecting against rockfalls, avalanches, landslides and other hazards. Forests then protect nearby populations and infrastructures. In other areas, forests play a useful role in combating erosion, maintaining soil, filtering water and so on".*

After this explanation, respondents were asked to answer five questions about natural insurance, focusing mainly on their situation regarding natural insurance. The questions and answer

[1] All information related to the questionnaire and the data is available in open access: Brunette, Marielle; Claise, Fanny, 2025, "Questionnaires - Forest insurance," https://doi.org/10.57745/PH39YH, Recherche Data Gouv, PROVISIONAL VERSION.

options are presented in Table 1.

We asked them about the current and future provision of natural insurance (Q1 and Q2), and whether they received or expected compensation for providing this service (Q3 and Q5). In some countries where forests are largely privately owned, natural insurance corresponds to a public good characterised by non-rivalry and non-excludability (Olschewski et al., 2012; Paavola and Primmer, 2019). This means that public compensation like tax benefit, direct payment or contract adoption may be useful in encouraging forest owners to provide the desired level of services. Finally, Q4 is about the management practices that may be implemented to facilitate natural insurance.

Question	**Description**	**Answer options**
Question 1	Does your forest property currently provide natural insurance for the society?	Yes / No / I don't know
Question 2	Is this a practice you'd like to encourage in the next 10 years?	Yes / No / I don't know
Question 3	Do you receive a compensation (tax benefit, direct payment, contract) for the provision of natural insurance from your forest property?	Yes / No / I don't know
Question 4	Do you think there is a way to improve natural insurance? Select all that apply:	Multiple choices possible • 4.1: Sustainable practices (e.g. no clear cut, proactive adaptation) • 4.2: Diversification of tree species • 4.3: Diversification of forest structure (e.g. uneven-aged system, multi-layer canopy) • 4.4: Restoration activities (e.g. soil treatment, plantation) • 4.5: I don't know
Question 5	Would you expect to receive a compensation (tax benefit, direct payment, contract) for improving the provision of natural insurance from your forest property?	Yes / No / I don't know

Table 1: Survey questions concerning natural insurance

2.3 Empirical strategy

Based on the answers at the five questions presented in Table 1, the objective of the empirical strategy is to better understand the forest owners' behavior towards natural insurance. To this end, we propose a multi-step approach combining descriptive statistics, behavioral clustering, and econometric modeling. First, descriptive statistics are used to summarize respondents' answers concerning the current provision (Q1), willingness to promote the provision in the future (Q2), current and expected compensation (Q3 and Q5), and preferred management practices (Q4) related to natural insurance. Second, a multivariate analysis combining Principal Component Analysis (PCA) and cluster analysis is implemented to identify behavioral typologies among forest owners. Third, econometric models are estimated to examine the determinants of (i) the current provision of natural insurance and (ii) the selection of management practices aimed at enhancing this function. This combined approach allowed for a comprehensive understanding of both the behavioral drivers among forest owners and the economic drivers influencing their engagement in nature-based solutions for forest resilience.

2.4 Econometric modelling

The final stage of the analysis relies on separated binary logit models to identify the socio-economic determinants of forest owners' natural insurance choices. This is a methodology used in Thomas et al. (2022) to explain adoption of adaptation strategies towards climate change among French private forest owners.

The first econometric model examines the determinants of the current provision of natural insurance function. The dependent variable corresponds to Question 1 of the survey and is defined as:

$$Q1_i = \begin{cases} 1 & \text{if the respondent answers "Yes"} \\ 0 & \text{otherwise} \end{cases}$$

The probability that respondent i indicates that her/his forest is currently providing natural insurance is modeled as:

$$P(Q1_i = 1) = \Lambda(X_i)\beta$$

where $\Lambda(\cdot)$ denotes the logistic cumulative distribution function, X_i is a vector of explanatory

variables, and β is the vector of estimated coefficients. The explanatory variables include socio-economic and ownership characteristics such as age, education, income, children, risk attitude, forest size, certification, insurance, and country fixed effects.

The second set of econometric models analyzes the determinants of preferences for forest management practices improving natural insurance. Separate binary logit models are estimated for each practice identified in Question 4: (i) sustainable practices; (ii) diversification of tree species; (iii) diversification of forest structure; (vi) restoration activities ; (v) "I don't know" responses.

For each practice k, the dependent variable is defined as:

$$Practice_{ik} = \begin{cases} 1 & \text{if the respondent i selects practice k} \\ 0 & \text{otherwise} \end{cases}$$

The estimated specification is:

$$P(Practice_{ik} = 1) = \Lambda(X_i)\gamma_k$$

where X_i includes the same set of socio-economic and ownership characteristics used in the previous model, and β is the vector of estimated coefficients. The estimated coefficients are interpreted in terms of the direction and statistical significance of the relationship between respondents' characteristics and the probability of supporting natural insurance-related management practices. We also calculated the marginal effects to analyze the magnitude of the effect.

2.5 Variable recoding

Several variables were recoded in order to facilitate interpretation and ensure sufficient observations within each category. Age was grouped into three categories corresponding to different stages of the life cycle and potentially different forest management behaviors: young owners (less than 45 years old), middle-aged owners (45-64 years old), and older owners (65 years and above). Education level was recoded into three categories (low, medium, and high), reflecting the respondent's highest level of education. In addition, a binary income variable ($income\_high$) was constructed and takes the value 1 when the respondent reported a monthly income above €3000, and 0 otherwise. Forest size was also recoded into three categories in order to capture differences in ownership structure and management capacity: small forests

(less than 10 hectares), medium-sized forests (10-100 hectares), and large forests (more than 100 hectares). Several binary variables were constructed. The variable *Insurance* takes the value 1 if the respondent owns a forest insurance contract covering natural hazards, and 0 otherwise. The variable *Certified* equals 1 when the forest property is certified under FSC and/or PEFC schemes.

The variable *SinceForester* equals 1 if the respondents reported being a forest owner since more than 15 years, and 0 otherwise. The variable *Children* equals 1 if the respondents has a child, 0 otherwise. Finally, the variable *ExperienceHazards* equals 1 if the respondent reported having experienced a natural hazard affecting the forest property during the previous five years, and 0 otherwise.

All respondents were presented with nine 50/50 lotteries, each defined by two possible monetary outcomes, and were asked to select the preferred lottery. The selected option is then used to construct a discrete risk preference indicator, denoted *Risk*, which corresponds to the chosen lottery number ranging from 1 (most risk-averse option) to 9 (most risk-seeking option).

3 Results

We present the results of our multi-step approach: descriptive statistics, cluster and principal component analyses and logit regressions.

3.1 Descriptive statistics

Table 5 in appendix shows the descriptive statistics of the sample for the full dataset and by country (Finland, France, Germany, and Spain). Overall, the "average" European forest owner is a middle-aged, highly educated male with a medium to high income, typically managing a small to medium-sized forest holding. He is more likely to have children, to be certified in sustainable forest management, and to have experienced natural hazards. However, important cross-country differences emerge: Finnish owners are more often certified, manage larger forest areas, and report more hazard exposure, whereas French, German and Spanish owners are more frequently small-scale forest holders with lower certification rates and higher reliance on non-certified management systems.

Table 2 below reports descriptive statistics for the main variables of interest by country, i.e.

the answers to the five questions presented in Table 1. The reported values are percentages within each group. The results highlight cross-country variation in both situation regarding the natural insurance function of forests and related management practices.

Question		Finland	France	Germany	Spain	Total
Q1. Current natural insurance	Yes	18.2	24.7	42.0	36.5	29.5
	No	57.5	45.6	33.6	37.0	43.9
	I don't know	24.3	29.7	24.4	26.6	26.6
Q2. Willingness to encourage	Yes	24.7	43.6	54.0	65.6	45.7
	No	28.3	23.3	23.6	9.4	22.0
	I don't know	47.0	33.1	22.4	25.0	32.3
Q3. Current compensation	Yes	7.3	14.7	22.4	16.7	15.2
	No	78.1	76.1	71.2	74.5	75.1
	I don't know	14.6	9.2	6.4	8.9	9.7
Q5. Expected compensation	Yes	59.9	48.9	68.0	68.8	59.7
	No	21.1	35.8	20.0	20.3	25.7
	I don't know	19.0	15.3	12.0	10.9	14.6
Q4. Management practices (excluding "I don't know" responses)						
0 management practice		2.11	0	0	1.88	0.8
1 management practice		33.2	45.5	37.1	51.2	41.7
2 management practices		30	34.3	29.4	32.5	31.8
3 management practices		18.9	13.7	19.8	9.38	15.5
4 management practices		15.8	6.50	13.7	5	10.1
Q4.1. Sustainable practices		25.9	45.0	45.2	37.0	39.1
Q4.2. Species diversification		57.1	40.0	43.2	32.8	43.5
Q4.3. Structure diversification		44.9	28.3	33.6	23.4	32.6
Q4.4. Restoration activities		36.0	26.1	44.0	43.8	35.9
Q4.5. I don't know		23.1	23.1	21.2	16.7	21.4
Observations		247	360	250	192	1049

Notes: Values correspond to percentages of respondents. Percentages by country are calculated within each national subsample.

Table 2: Descriptive statistics by country (%)

Overall, one third of the sample indicated that their forest currently provide natural insurance (Q1). This suggest that the supply of this function is real in European forests. However, this provision varies considerably across countries, ranging from 18.2% in Finland to 42% in Germany. The proportion of respondents indicating "I don't know" is quite stable across countries with around 25% of the sample. This result seems to indicate that the respondents are not familiar with the notion of natural insurance, and it is not surprising since it is still an emergent concept.

Concerning Q2, 45.7% of the sample are willing to encourage this function in the future with

again large heterogeneity between countries with 24.7% in Finland, up to 65.6% in Spain. We take note of the large proportion of respondents indicating "I don't know" in Finland.

Current compensation mechanisms (Q3) remain relatively limited with only 15.2% of the sample attesting already receiving compensation for the provision of natural insurance function. This compensation seems more used in Germany with the highest share (22.4%), suggesting a more developed integration of economic instruments for ecosystem service provision. Less than 10% of the sample indicated "I don't know" suggesting that, even though is it not current, European private forest owners are well-informed about economic incentives to provide natural insurance service.

Expected compensation for improving natural insurance (Q5) is high with 60% of the sample with a positive response. This is true in all countries, particularly in Germany (68.0%) and Spain (68.8%). This result suggests that compensation may be a relevant option to encourage the provision of natural insurance among private forest owners in Europe.

Some heterogeneity is also observed regarding forest management practices. The number of management practices selected by the forest owners varies between countries, but the trend is similar: "1 management practice" > "2 management practices" > "3 management practices" > "4 management practices" > "0 management practices". In Spain, the choice of "1 management practice" accounts for up to 50% of the sample whereas accounting only for 33.2% in Finland. Additionally, the percentage of those who have chosen "0 management practices" is very low, indicating their belief that adequate management practices can improve the provision of natural insurance. There is more heterogeneity between countries regarding the selection of "4 management practices", with only 5% of the sample selecting 4 practices in Spain and up to 15.8% in Finland.

Concerning the type of practices, sustainable management practices are more frequently preferred to increase natural insurance in France (45%) and Germany (45.2%), while Finland exhibits lower levels (25.9%). Species diversification is particularly preferred in Finland (57.1%), whereas it is less common in Spain (32.8%). Structural diversification follows a similar pattern, with higher level in Finland (44.9%) compared to Southern European countries. Restoration activities appear relatively widespread across all countries, with notably high values in Germany (44%) and Spain (43.8%). Concerning the "I don't know" option, it is selected by around 15-20% of the sample in each country, indicating that some forest owners are still few informed about this natural insurance function.

Pearson's chi-square tests were then conducted to determine whether the responses to the questions about natural insurance are independent of the country or not. In other words, they test whether the differences observed between Finland, France, Germany, and Spain reflect national differences.[2] The results of the test are presented in Table 7 in Appendix B. They reveal significant cross-country differences in natural insurance provision and preferred forest management practices aimed at strengthening this function. Chi-square tests indicate that the adoption of sustainable management practices ($\chi^2 = 27.58$, $p < 0.001$), species diversification ($\chi^2 = 29.28$, $p < 0.001$), structural diversification ($\chi^2 = 27.55$, $p < 0.001$), and restoration activities ($\chi^2 = 27.25$, $p < 0.001$) all vary significantly across countries. By contrast, no significant difference was found regarding the share of respondents answering "I don't know" to Question 4 ($\chi^2 = 3.56$, $p = 0.314$).

3.2 Principal Component Analysis and cluster analysis

A principal component analysis (PCA) was first conducted to reduce the dimensionality of forest owners' responses regarding natural insurance and forest management practices. PCA creates new variables, which are linear combinations of the original variables. The first components capture key gradients related to engagement and management practices.

These components were then used as inputs for a k-means cluster analysis, allowing us to identify distinct profiles of forest owners. K-means is a clustering algorithm that assigns data points to clusters (groups based on their distance from the cluster centers). It takes as input a dataset containing one or more variables and produces a set of clusters containing similar data points.

The optimal number of clusters is determined using the within-cluster sum of squares (WSS) criterion. We then apply a k-means clustering algorithm on the first two principal components. Multiple random starts are used to ensure the stability of the clustering solution. Figure 1 displays the distribution of forest owners across clusters in the space defined by the first two principal components and Table 3 shows the results.

[2]The null hypothesis is H0: the responses are independent of the country. The alternative hypothesis is H1: the responses depend on the country.

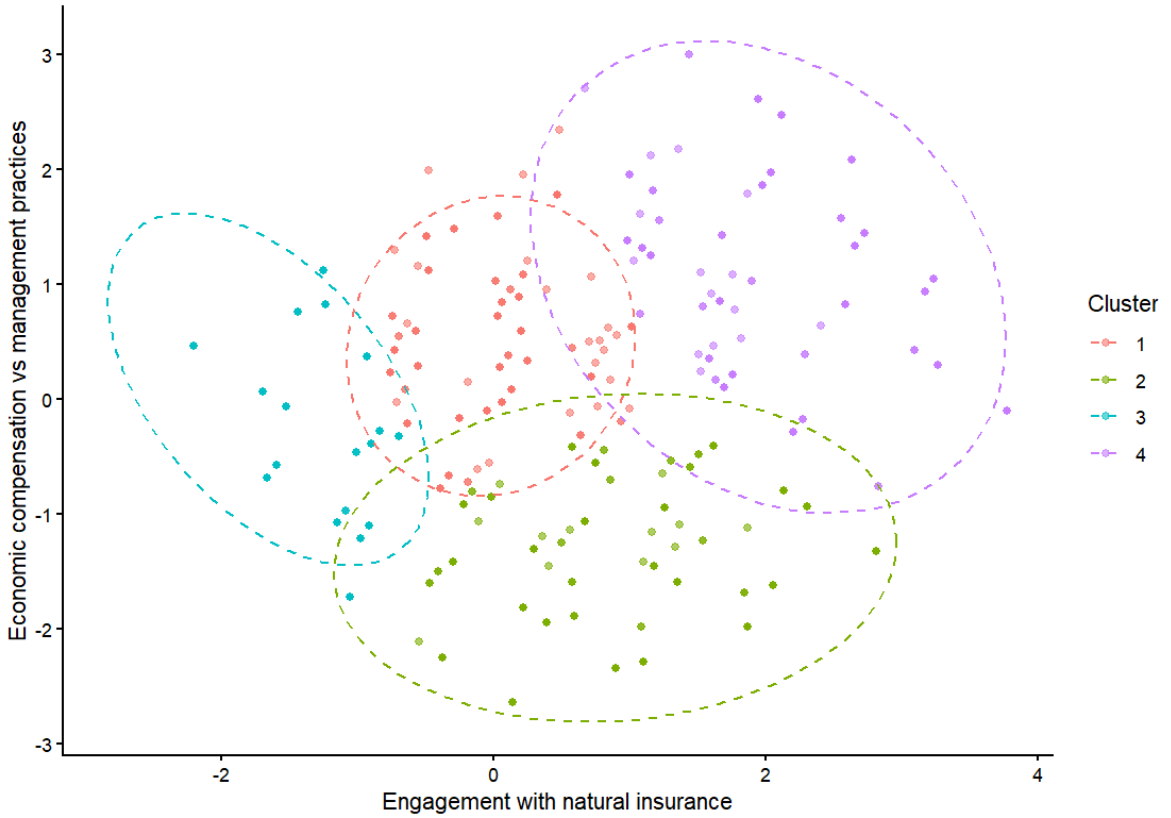

Figure 1: Result of the Principal Component Analysis - Clusters defined by the two first principal components

The loading values of the two components PC1 and PC2 allow us to construct the two axes. The larger the absolute value, the more the variable "constructs" the axis. PCA scores are standardized coordinates with zero mean and unit variance inputs; therefore, the resulting principal components are not bounded and typically range between -3 and +3, reflecting the distribution of respondents along latent behavioral dimensions.

The first component (PC1), on the X-axis, reflects overall engagement with the natural insurance function (considering the answers to the five questions). All variables included in the analysis load positively on this axis, including current and future natural insurance provision, current and expected compensation (Q1, Q2, Q3, Q5) as well as the preferred management practices (Q4).[3]

For the second component (PC2), the Y-axis is mainly driven by strong positive loadings on current compensation (Q3), and strong negative loadings on management practices, in particular

[3]excluding Q4.5 "I don't know". When this variable is added, the analysis becomes unstable.

species diversification, structural diversification, and sustainable management practices. More precisely, higher values of this component are associated with respondents who report a compensation but show relatively lower engagement in favor of management practices.

	Cluster 1 Incentive-sensitive	**Cluster 2** Proactive managers	**Cluster 3** Disengaged	**Cluster 4** Highly engaged
Q1. Current natural insurance	0.31	0.27	0.01	0.86
Q2. Willingness to promote	0.60	0.58	0.03	0.97
Q3. Current compensation	0.11	0.01	0.00	0.68
Q5. Expected compensation	0.71	0.73	0.27	0.95
Q4.1 Sustainable practices	0.37	0.71	0.10	0.61
Q4.2 Species diversification	0.24	0.94	0.24	0.45
Q4.3 Structural diversification	0.13	0.77	0.13	0.40
Q4.4 Restoration	0.38	0.56	0.17	0.48
Distribution across countries (%)				
Finland	16.0	37.1	45.9	6.3
France	23.6	20.3	41.9	14.2
Germany	20.8	20.4	29.2	29.6
Spain	32.4	13.1	26.7	28.3
Cluster size (N)	237	237	384	191
Share of sample	0.23	0.23	0.37	0.18

Notes: Values correspond to cluster-specific means of binary variables. Clusters are derived from a k-means algorithm applied to the first two principal components of the dataset.

Table 3: Typology of forest owners based on PCA and k-means clustering

The cluster analysis reveals four distinct behavioral profiles of forest owners, highlighting substantial heterogeneity in natural insurance and management responses.

Cluster 3, the largest group (37% of the sample) corresponds to disengaged forest owners, characterized by very low levels of current natural insurance, willingness to promote in 10 years, and few preferences for management practices. This profile reflects a form of passive ownership, consistent with the literature on "indifferent" or "non-interventionist" forest owners, where forests are not actively managed for ecosystem service provision.

In contrast, Cluster 4 represents highly engaged forest owners (18% of the sample). They strongly recognize the natural insurance function (Q1 = 0.86), are willing to promote it (Q2 =

0.97), and exhibit high levels of both current and expected compensation. They also display relatively high adoption of management practices, including sustainable management and diversification strategies.

Cluster 2 is composed of proactive managers, representing 23% of respondents. They strongly adopt diversification practices, despite moderate levels of natural insurance and relatively limited interest for compensation. This suggests that their behavior is primarily driven by intrinsic or management objectives rather than economic incentives or explicit recognition of the insurance function.

Finally, Cluster 1 corresponds to incentive-sensitive owners (23% of the sample), who express a willingness to promote natural insurance (Q2 = 0.60) but exhibit relatively low adoption of practices, suggesting that their engagement may depend on economic incentives.

The distribution of clusters differs significantly across countries ($X^2 = 113.2$, $p < 0.001$), indicating that national contexts and institutional environments play a key role in shaping forest owners' behaviors. Cluster 3 (disengaged owners) is particularly prevalent in Finland, where nearly half of respondents fall into this category. Cluster 4 (highly engaged owners) is more prevalent in Germany and Spain, suggesting stronger integration of ecosystem service awareness and compensation mechanisms in these countries. France, by contrast, shows a more balanced distribution but remains characterized by a substantial share of disengaged owners.

These results highlight the coexistence of multiple behavioral logics among forest owners. While some are intrinsically motivated or already engaged, others appear to condition their behavior on the presence of economic incentives. This finding supports the hypothesis that the provision of ecosystem services, such as natural insurance, is shaped by both individual perceptions and economic considerations.

3.3 Econometric results

Table 4 presents the results of the six logit regressions trying to identify determinants of current natural insurance provision (1) and the adoption of each management practice: sustainable practices (2), species diversification (3), structural diversification (4), restoration (5) and "I don't know" (6). By providing a regression by practice, we follow Thomas et al. (2022).

	(1)	(2)	(3)	(4)	(5)	(6)
	Current Natural Insurance (Q1)	Sustainable (Q4.1)	Species div. (Q4.2)	Structure div. (Q4.3)	Restoration (Q4.4)	Don't know (Q4.5)
Male	0.188	0.132	0.284*	0.241	-0.030	-0.369*
	(0.177)	(0.153)	(0.151)	(0.165)	(0.152)	(0.174)
Age (Middle)	0.025	-0.654**	-0.135	0.031	-0.236	0.440
	(0.308)	(0.266)	(0.257)	(0.259)	(0.258)	(0.369)
Age (Older)	-0.138	-1.050***	-0.042	-0.786**	0.022	0.664
	(0.389)	(0.309)	(0.299)	(0.327)	(0.301)	(0.407)
Income (High)	-0.338*	0.488***	0.021	0.246	0.164	-0.179
	(0.174)	(0.148)	(0.146)	(0.157)	(0.149)	(0.178)
Certified	1.163***	0.417***	0.503***	0.706***	0.068	-1.048***
	(0.175)	(0.156)	(0.150)	(0.158)	(0.153)	(0.205)
Education (Medium)	1.016***	0.033	0.136	0.461	0.562*	-0.308
	(0.346)	(0.287)	(0.283)	(0.318)	(0.292)	(0.306)
Education (High)	0.919***	0.333	0.590**	0.527*	0.764***	-0.516*
	(0.326)	(0.262)	(0.261)	(0.296)	(0.269)	(0.281)
Experience hazards	0.354**	0.189	0.307**	0.356**	0.106	-0.703***
	(0.173)	(0.156)	(0.151)	(0.158)	(0.154)	(0.211)
Children	0.688***	0.262	0.325*	0.218	0.056	-0.306
	(0.242)	(0.190)	(0.183)	(0.195)	(0.184)	(0.206)
Insurance	0.629***	0.269*	0.298**	0.019	0.498***	-0.528**
	(0.163)	(0.145)	(0.141)	(0.151)	(0.145)	(0.181)
Forest size (Medium)	0.199	0.434	0.425*	0.417*	0.501**	-0.444
	(0.286)	(0.266)	(0.239)	(0.245)	(0.250)	(0.300)
Forest size (Small)	-0.110	0.510*	0.289	0.145	0.387	-0.259
	(0.310)	(0.290)	(0.270)	(0.282)	(0.280)	(0.345)
Since forester	0.149	-0.044	-0.021	0.094	0.006	0.070
	(0.157)	(0.137)	(0.135)	(0.145)	(0.138)	(0.164)
Risk	0.008	-0.024	0.032	-0.034	-0.014	0.013
	(0.030)	(0.027)	(0.026)	(0.028)	(0.027)	(0.031)
France	1.317***	0.909***	-0.487**	-0.296	-0.478**	-0.707*
	(0.281)	(0.235)	(0.226)	(0.234)	(0.233)	(0.294)
Germany	2.367***	0.971***	-0.322	-0.021	0.470**	-0.893**
	(0.288)	(0.240)	(0.231)	(0.238)	(0.232)	(0.309)
Spain	1.646***	0.712***	-0.876***	-0.607**	0.422*	-1.075***
	(0.291)	(0.250)	(0.242)	(0.254)	(0.239)	(0.321)
Observations	1049	1049	1049	1049	1049	104
AIC	1106.1	1342	1375.3	1246.6	1337.2	1019.8

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Table 4: Logit models of current natural insurance and preferred forest management practices

The regression (1) allows to identify the determinants of the current natural insurance provision among private forest owners in Europe. We observed that several variables have a significant and positive impact on the provision like having a certification, medium and high education level (as compared to a low level), already suffered from a natural hazard in the past, children, insurance contract, and having forest in France, Germany or Spain (as compared to Finland). Only one variable has a significant and negative effect: high income (above 3000 euros per month, compared to lower income levels), suggesting that wealthier forest owners are less likely to report their forest as currently providing natural insurance.

Some of these variables have already proved to significantly explain other forestry decisions. For example, certification and income (high) have the same significant impact on French forest owner's insurance demand (Claise and Brunette, 2025b). The variable certification has also a significant effect on the harvesting decisions of French private forest owners (Brunette et al., 2017). Some absence of effect is also well-documented with the non-significance of risk attitude on some forestry decisions like adaptation for example (Brunette et al., 2020).

The other four regressions identified the determinants of the preferred management practices. The only one variable having a significant impact (although differentiated) on the fourth strategies is Spain. For the strategy "Sustainable practices", being older has a significant and negative impact on the adoption, whereas variables like high income (compared to lower income levels), being certified, having an insurance contract, a small forest size (as compared to large one), and having a forest in France, Germany and Spain (as compared to Finland) have a significant and positive impact. For the strategy "Diversification of tree species", some variables have a significant and positive effect such as being certified, having a high education level (as compared to low one), having already suffered from a hazard occurrence in the past, having children, insurance contract and a medium forest size (as compared to a large one). Living in France or Spain seems to have a significant and negative effect on species diversification, compared to living in Finland. For the strategy "Diversification of forest structure", being older and living in Spain have a negative impact whereas all the other significant variables have a positive effect: certified, high education, experience hazards and medium forest size. Finally, for the strategy "Restoration activities", living in France has a negative impact whereas the other significant variables have a positive effect: medium and high education, insurance, medium forest size, Germany and Spain.

Concerning the management practices, our conclusions are the following ones. First, the determinants are practice-dependent. In this sense, our conclusion aligned with Thomas et al. (2022). Second, the variables associated to the countries are very often significant meaning that

the type of practices that appeared to favor natural insurance is country-dependent with the France, Germany and Spain favoring "sustainable" compared to Finland, and differentiated results for the other practices.

The regression results for the "I don't know" response to the question on potential improvements to natural insurance (model 6) reveal several significant determinants. Interestingly, the significant coefficients point in the opposite direction from those in the previous regressions. This therefore provides clear insights into the behavior of individuals who select "I don't know". Certification status has a strong negative effect, indicating that certified forest owners are significantly less likely to report uncertainty. Similarly, experiencing natural hazards in the past and holding a forest insurance contract both reduce the probability of answering "I don't know". At the country level, respondents in France, Germany, and Spain are significantly less likely than those in Finland to express uncertainty.

4 Discussion

This study identifies distinct behavioral profiles among European forest owners with respect to the natural insurance function of forests. The results reveal some heterogeneity in management practices, as well as clear differences in the role of economic incentives.

These results are consistent with previous research emphasizing the diversity of forest owner objectives and motivations, which often combine economic, environmental, recreational, and patrimonial dimensions.

At the same time, the identification of "incentive-sensitive" forest owners suggests that economic compensation mechanisms may nevertheless constitute an important lever for encouraging the provision of ecosystem services associated with forest resilience. This raises broader questions regarding the design of policy instruments capable of supporting the natural insurance function of forests. Payment for ecosystem services (PES) schemes could represent one possible mechanism to compensate forest owners for management practices that generate collective benefits, such as reduced vulnerability to storms, fires, pests, or droughts. Other approaches, including regulatory instruments, public co-financing, or insurance-related incentives, may also contribute to supporting the adoption of resilient forest management practices.

In this perspective, our results contribute to the emerging debate on the economic organization of natural insurance mechanisms. While previous work by Unterberger and Olschewski

(2021) demonstrated the existence of a demand for ecosystem-based insurance solutions, our study provides evidence of a potential supply side, namely forest owners willing to engage in management practices that enhance ecosystem resilience. The challenge therefore lies not only in recognizing the insurance value of ecosystem services, but also in designing institutional and financial arrangements capable of connecting demand and supply. This includes questions related to the scale of implementation, the valuation of ecosystem services, the choice of compensation vehicles, and the governance structures.

Finally, some limitations of the study should be acknowledged. The analysis relies on self-reported survey data, which may be affected by reporting biases or differences in interpretation across countries. Moreover, the study focuses on stated behaviors and attitudes rather than observed long-term management outcomes. Future research could further investigate how behavioral profiles translate into actual forest management practices over time and explore the economic feasibility of specific compensation or insurance mechanisms supporting natural insurance provision.

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A Tables presenting descriptive statistics

Variable	Modality	Finland	France	Germany	Spain	Full sample
Gender	Male	76.9	69.4	70	72.4	71.9
Age group	Young	14.6	5.0	6.0	3.1	7.1
	Middle	80.2	71.9	72.8	77.6	75.1
	Older	5.3	23.1	21.2	19.3	17.7
Income high	Yes	39.3	68.9	63.6	31.8	53.9
	No	60.7	31.1	36.4	68.2	46.1
Certification	Certified	69.6	28.9	35.2	45.3	43.0
	Not certified	30.4	71.1	64.8	54.7	57.0
Education	High	57.1	71.1	67.6	64.6	65.8
	Medium	37.2	26.1	10.8	28.1	25.5
	Low	5.7	2.8	21.6	7.3	8.8
Experience hazards	Yes	51.0	18.9	28.0	25.5	29.8
	No	49.0	81.1	72.0	74.5	70.2
Children	Yes	74.5	90.6	76.0	84.4	82.2
	No	25.5	9.4	24.0	15.6	17.8
Insurance	Yes	61.9	39.7	36.8	43.8	45.0
	No	38.1	60.3	63.2	56.2	55.0
Forest size	Large	28.7	2.5	4.8	5.7	9.8
	Medium	69.6	24.2	28.0	23.4	35.7
	Small	1.2	73.1	67.2	70.8	54.3
Since forester	More than 15 years	55.5	43.1	57.6	44.8	49.8
Risk	Mean	3.72	3.32	3.40	3.68	3.5

Table 5: Descriptive statistics by country and for the total sample (%)

	Overall	Finland	France	Germany	Spain
Emotional attachment	58.4	42.9	70.3	52.8	63.5
Family heritage	48.1	65.2	38.9	49.2	42.2
Tax benefits	8.5	5.7	9.4	8.0	10.9
Hunting territory	13.8	31.6	8.6	9.6	6.3
Wood self-use	36.8	52.2	34.4	44.4	11.5
Industrial wood	27.8	80.6	9.2	16.0	10.4
Biodiversity	45.1	66.0	36.4	45.2	34.4
Gathering	32.1	46.2	32.8	26.4	20.3
Recreation	26.1	23.1	23.3	34.8	24.0
Freedom space	29.3	27.9	29.4	28.4	31.8

Table 6: Share of forest owners reporting each motivation (% Yes)

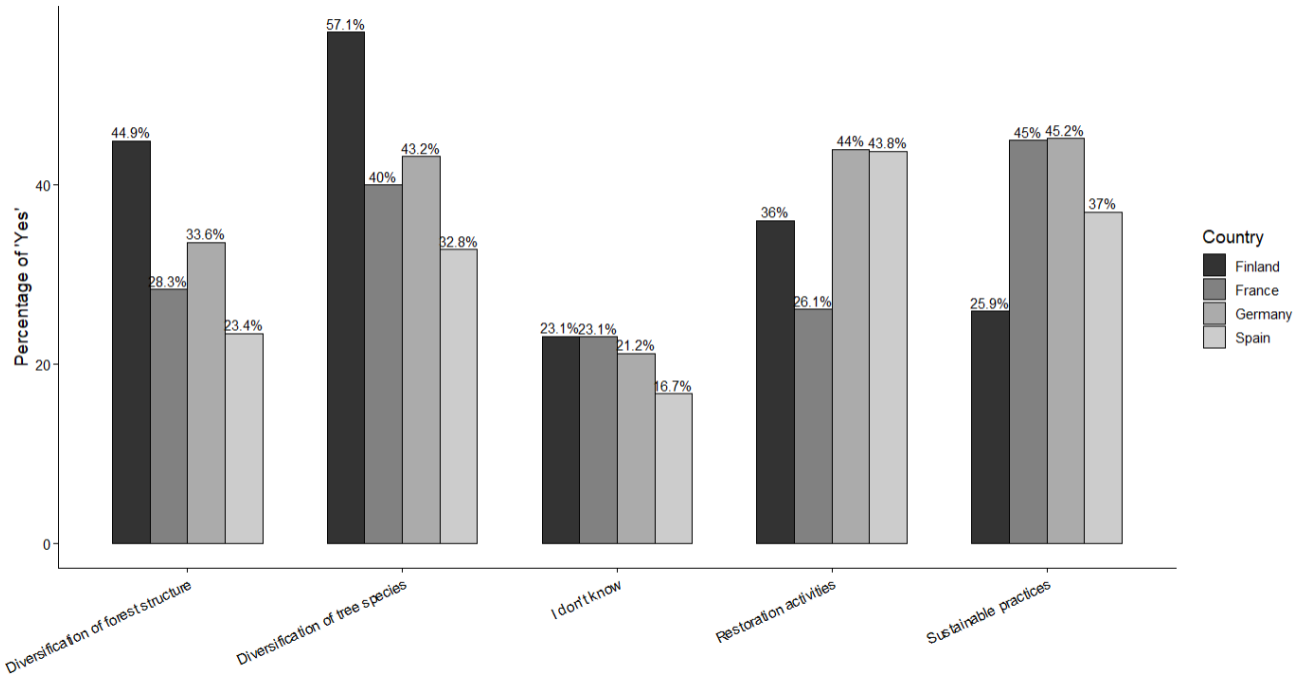

Figure 2: Preferred management practices, by country

B Independence test

Variable	χ^2 statistic	Degrees of freedom	p-value
Q1. Current natural insurance	50.879	6	3.13×10^{-9}***
Q2. Willingness to promote	90.904	6	$< 2.2 \times 10^{-16}$***
Q3. Current compensation	29.029	6	6.01×10^{-5}***
Q5. Expected compensation	40.688	6	3.34×10^{-7}***
Q4.1. Sustainable management practices	27.580	3	4.45×10^{-6}***
Q4.2. Species diversification	29.278	3	1.96×10^{-6}***
Q4.3. Structural diversification	27.547	3	4.52×10^{-6}***
Q4.4. Restoration activities	27.248	3	5.22×10^{-6}***
Q4.5. "I don't know" responses	3.556	3	0.314

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 7: Chi-square tests of independence between country and natural insurance questions