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Insurance Demand Against Natural Hazards by Forest Owners: A French Case Study Using Discrete Choice Modeling

Fanny Claise [*], Marielle Brunette [†]

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Abstract

Natural events pose a real threat to forests around the world. Insurance contracts can help protect forest owners against these damaging events. However, there is considerable heterogeneity in terms of insurance adoption across countries. In France, for instance, the adoption rate is extremely low. In this article, we attempt to identify the characteristics of insurance contracts that influence forest owners' demand for insurance against natural events. To this end, we employed a Discrete Choice Experiment methodology involving hypothetical forest insurance scenarios that varied according to the characteristics of the insurance contract such as the hazard(s) covered, the level of deductible, the duration, and the annual cost. The results, based on 317 responses from French private forest owners, demonstrate that some of the tested characteristics had a significant impact. Notably, forest owners were not willing to pay for storm insurance in addition to fire insurance. Conversely, they were willing to pay for insurance against the package including all hazards: fire, storm, drought and pathogens.

Keywords: Forest Insurance; Discrete Choice Experiment; Contract; Logit; Willingness to pay (WTP); Contract
JEL Codes: B21, G22, Q23

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1 Introduction

Natural events pose a real threat to forests around the world. The State of the World's Forests report of 2024 says there is evidence that climate change is making forests more vulnerable to natural hazards especially wildfires and pests. In Europe, damage due to various disturbances over the last 20 years accounted for a timber volume of 44 million m^3, i.e. 16% of the mean annual harvest (Patacca et al., 2023). Windstorms accounted for 46% of the total damage, fire for 24% and bark beetles for 17%. The magnitude and frequency of these natural hazards is expected to increase due to climate change. This trend is already observed and tends to be stressed (Seidl et al., 2011). Schelhaas et al. (2003) thus show that the damage caused by wind, fire and insects drastically increased over the period 1958-2001.

In addition to these changes in the regime of natural hazards, climate change also favours the interactions between disturbances (Gallina et al., 2016; Seidl et al., 2011, 2017; Susaeta et al., 2014). According to Hanewinkel et al. (2011), drought episodes are becoming more frequent and severe, impacting tree growth and making them more susceptible to diseases and pests. For instance, bark beetles have severely impacted spruce forests in central Europe with trees weakened by repeated droughts being highly susceptible to infestation (Hlasny et al., 2019). Many studies confirm that insect outbreaks occur as a consequence of previous abiotic disturbances (Hanewinkel et al., 2008; Müller et al., 2002).

Several options exist to protect against these hazards and forest insurance is one of them. Forest insurance offers financial protection for private forest owners. The role of insurance as a means of financing resilience and adaptation to climate change is a topic that has been presented by international bodies and reported upon (OECD, 2015; Global Agenda Council on Climate Change, 2014; Article 4.8 of the United Nations Framework Convention on Climate Change (UNFCCC) and Article 3.14 of the Kyoto Protocol) (Brunette and Couture, 2023). By taking out a damage insurance policy, forest owners can protect their assets from potential losses caused by some natural hazards. This type of policy enables forest owners to transfer the financial risk of natural events to the insurer in exchange for an insurance premium, thereby safeguarding both the economic value of their forest and the future income it generates. In an era of increasing climate-related risks, forest insurance provides a vital financial tool for forest owners, enhancing resilience and supporting sustainable forest management.

However, despite its potential benefits, there are huge differences in insurance coverage from one country to another. For example, the adoption of forest insurance by private owners represents almost 60% of private forest area in Denmark, whereas it remains low in other European countries such as France with less than 10% of private forest area insured against fire and/or storm (Brunette et al., 2009). This low adoption rate is problematic in the context of increasing natural disturbances due to climate change. Indeed, natural hazards in forest result in substantial economic losses for private forest owners, due to reduced timber quality, decreased future stand value, increased restoration costs, and a loss of income (Brunette and Hanewinkel, 2023). Consequently, forest owners are facing mounting challenges in safeguarding their assets, so a better understanding of the factors influencing their adoption of insurance is crucial. This is precisely what we propose to explore in this article taking the case study of France.[1]

The literature is not very developed on forest insurance, since only 38 articles were published between 1928 and 2021 (Brunette and Couture, 2023), even if most of the literature appeared after 2000. The literature review of Brunette and Couture (2023) show that among the issues of interest is the identification of determinants of insurance demand, especially through empirical studies like surveys (Brunette et al., 2020; Dai et al., 2015; Deng et al., 2015; Gan et al., 2014; Mensah et al., 2021; Parajuli et al., 2019; Qin et al., 2016). In these articles, they try to identify determinants of forest owners' insurance demand using variables mainly from the owners' characteristics and characteristics of the forest property. For example, in the U.S., Deng et al. (2015) showed that Mississippi landowners were willing to pay a higher insurance premium if their first objective for timberland ownership was timber revenue, if they were risk averse and had substantial income, if they had previously experienced a loss, and if they were concerned about risks to standing timber.

In these articles, the determinants come from the demand side of the insurance market only and were identified among the characteristics of the forest property and the forest owners.[2]

However, the determinants may also come from the supply side of the insurance market. Indeed, there is a lack of competition on the forest insurance market (Sauter et al., 2016), particularly in France with three insurers sharing the market Wang et al. (2025). This low

[1] France is not an isolated case where forestry insurance doesn't work. Other European countries, such as Germany, also have very low or non-existent adoption rates, with less than 10% of private forest area insured against fire and/or storm (Brunette et al., 2009).

[2] This is not particular to forestry literature, since other papers deal with the determinants of the insurance demand and focus on similar variables. For example, Showers and Shotick (1994) used as explanatory variables the households' characteristics such as income, family size and age, whereas Yuan and Jiang (2015) considered the level of education, the development of social security pensions, the child dependency ratio, and the elderly dependency ratio to explain the demand for life insurance.

offers and the low associated demand result in high transaction costs and high premiums (Holecy and Hanewinkel, 2006; Zhang and Stenger, 2014). The French private forest owners complain with this high level of insurance premium, but also with the mismatch of the existing contracts with their needs, and the low flexibility of the offers. Consequently, in this article, we propose identifying the determinants of the forest owners' demand for insurance from the perspective of the supply side of the insurance market by varying the characteristics of the insurance contracts (hazards, deductible rate, duration, cost). We also want to estimate how much French private forest owners are prepared to pay for these various features of the policy.

To do that, we propose to implement a discrete choice experiment (DCE) in France. This methodology is particularly relevant to our study since it enables us to create hypothetical scenarios for insurance contracts that do not yet exist on the forest insurance market. We can then test the owners' preferences for new characteristics that are generally not taken into account in current contracts in France. The DCE methodology has been widely employed in environmental economics to assess preferences for various ecosystem services and insurance products. However, there are no specific applications focused on forest insurance against natural hazards. To our knowledge, Sauter et al. (2016) is the only article using a DCE to investigate German foresters' insurance decisions for storm and fire risks and study the effect of public compensation and premium subsidization. Our DCE consider four attributes corresponding to four main characteristics of the forest insurance contract: (multi-)hazard(s) covered, deductible level, duration and annual cost.

We implemented this DCE at a national scale on a population of French private forest owners and we collected 317 full responses. We show that some of the tested characteristics have a significant impact in the Multinomial Logit model. Private forest owners prefer "full package" contract, and they are less inclined to choose contracts with higher deductible rates and higher insurance premiums. Finally, we discuss these results in relation to the development of the forest insurance market.

The remainder of our paper is structured as follows. First, we describe our case study, forest insurance in France and its specificities. Second, we describe the discrete choice experiment framework and the econometric specifications. Next, we present the data and the results. Finally, we conclude by discussing our findings and their implications for the insurance market and forest sector, as well as addressing the limitations of our work and avenues for future research.

2 Description of the case study

A key feature of French forests is the predominance of private ownership. In France, three quarters of the forest is privately owned (i.e., 12.3 million hectares) by 3.8 million owners (CNPF, 2021). Consequently, the management of natural hazards is largely a decision taken at forest property level by the private owner.

The hazards affecting French forests are similar to those affecting European forests, mainly fires and storms. Concerning storms, Lothar and Martin in 1999 caused widespread devastation, damaging more than 140 million cubic meters of wood across France. More recently, the 2009 Klaus windstorm destroyed 30% of the standing timber volume in the Landes de Gascogne in southern-west France. For wildfire, the year 2022 was particularly catastrophic in France with unprecedented fires in the Landes region burning more than 20,000 hectares. As for the rest of Europe, natural hazards are more and more linked one with the others both in time and space. For example, the forest in south-western part of France was impacted by three cascading events these last years : drought, fire in 2022 and bark beetles outbreak the years following the fire.

The French storms of 1982, 1984, 1987 and 1990 were compensated under the Cat Nat system. This is a public fund that compensates losses due to catastrophic events. The Herta storm of February 1990, which mowed down 100 Mm3 of timber in northern France, the Benelux countries and southern Germany, was the last to be treated as a natural disaster and compensated under the Cat Nat system. To preserve the accounts of the Cat Nat system, the French legislator excluded the effects of wind on forests, considering them to be "insurable". The only way to receive compensation in the event of a storm is to take out an insurance policy. Private forests are thus regarded as property by insurers, and the contracts they offer are "damage" insurance contracts.

To boost the take-up of insurance, the French government has decided to introduce monetary incentives via tax credits. The tax credit is 76% of eligible storm and fire insurance contributions, up to a ceiling of €15/ha (CNPF, 2023). French government has introduced a number of obligations that will enable private forest owners to obtain the tax credit of the "DEFI Forêt" scheme, including providing proof that their plots of land are properly insured against the risk of storms and fires. The owners must therefore provide an insurance certificate specifying the hectares covered for the current tax year.

In France, the insurance market is characterized by both low demand and limited supply.[3] Indeed, currently three insurance companies share the market: *Groupama Forêts Assurances* with 45% of the insured area, *Pacifica-XLB* with 35% and *Sylvassur* with 15%. They insure approximately 9% of the French private forest area (Adrast, 2022).

The first forest insurance contract appeared in France in 1947 under the impetus of the "Mutuelle Indépendante des Sylviculteurs du Sud-Ouest" (MISSO) to cover against fire events in the south-west part of France. Today, the contracts they propose allow to cover against fire and/or storms. Most of them include deductible rate, are taken for one year and cost between €5/ha and €6.5/ha (Hanewinkel et al., 2008).

This is precisely the impact of these characteristics of the insurance contract on the private forest owners' demand for insurance that we want to test through a DCE.

3 Questionnaire design

The questionnaire was an online survey, elaborated on LimeSurvey, with the help of the National Centre of Private Forest Property (CNPF)[4] The questionnaire was administered to private forest owners by a private survey company from September to October 2024. The company leveraged its respondent panel, targeting French forest owners, at a national scale in metropolitan France. This study focuses on private forest owners, since they make the decision to take out insurance. Respondents were asked to complete the survey on computers, with an average time spent answering the questionnaire of 15 minutes.

The study is composed of five part as presented in the Fig. 1 below: (1) questions on the forest property characteristics, (2) DCE with six choice cards, (3) risk test to elicit attitudes towards risk, (4) past experiences with forest disasters and insurance, and (5) socio-economic characteristics.

[3] More information on the French forest insurance market are provided in Wang et al. (2025).

[4] The National Centre of Private Forest Property is the public body responsible for developing the sustainable management of private forests: some 3.5 million French forest owners covering 12.6 million hectares, or around 23% of French land.

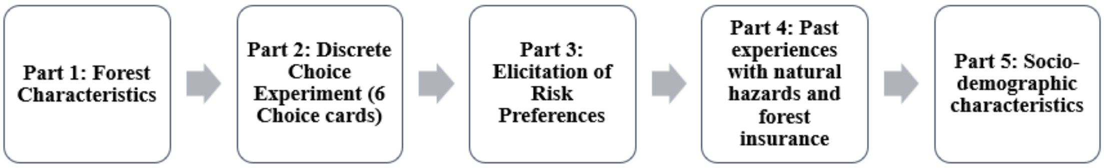

Figure 1: Questionnaire structure

Concerning Part (1) about the forest characteristics, we collected classical variables (presented in Table 4 in Appendix A) such as the forest area, mode of ownership (heritage, purchase, etc.), regional location, period of forester (since less than 5 years, etc.), forest composition and certification. For Part (3), we measure the forest owner's risk aversion through an Ordered Lottery Selection (OLS) methodology proposed by Reynaud and Couture (2012), which is an adaptation of the tasks by Eckel and Grossman (2008). For Part (4), we ask the respondents if they have been confronted with natural hazards impacting their forest in the last 5 years and if they have a forest insurance contract, as presented in Table 5. For the last part (5), the information demanded were presented in Table 6 in Appendix A and were about gender, having children or not, age, professional category, education level and income level.

3.1 The Discrete Choice Experiment

In this study, we conducted a DCE to elicit private forest owners preferences concerning forest insurance contract. This method is particularly well-suited for capturing the trade-offs respondents are willing to make between various attributes of a decision. The respondent is facing hypothetical forest insurance policy scenarios, e.g a number of choice cards. In these choice cards, the respondents must indicate their preferences between two insurance contracts with different characteristics (Contract A or Contract B), or s/he can decide not to insure.

3.1.1 Focus group and attributes definition

We conducted a focus group with 30 forest owners in a village in the Grand Est region of France (Abreschviller), which allowed us to test and refine the attributes and their levels. During the focus group, we discussed the relevance and clarity of the selected attributes. This iterative process enabled us to adjust the attributes and their levels based on the participants' feedback, ensuring that they accurately reflect the preferences and decision-making processes of the target population. Finally, based on the results of the focus group, we decided to keep four attributes, that are described in Table 1. We relied on forest insurance literature, discussions with forest stakeholders and existing insurance contracts to calibrate attribute levels.

Attributes	Levels
Hazard(s) covered	(1) fire
	(2) storm
	(3) fire & storm
	(4) fire & storm & pathogens
	(5) fire & storm & drought
	(6) fire & storm & drought & pathogens
Deductible rate	(1) 10%
(in %)	(2) 15%
	(3) 30%
Duration of the contract	(1) 1 year
(in years)	(2) 2 years
	(3) 5 years
Annual cost of the insurance	(1) €5/ha
(in euros per hectare)	(2) €10/ha
	(3) €15/ha
	(4) €20/ha
	(5) €25/ha
	(6) €30/ha

Table 1: Description of the attributes and their levels

We focus on some of the key attributes typically found in forest insurance contracts.

Firstly, the attribute concerning the types of hazard covered by the contract is crucial. Here, we focus on the main hazards affecting French forests - fire, storm, pathogens[5] and drought - and consider combinations of hazards to capture potential demand from forest owners for "multi-hazard" contracts. Even more interestingly, we consider potential demand for cover against hazards that are not yet covered by insurance policies in France, such as pathogens and drought.

Currently in France, it is possible to insure against fire alone (1), storm alone (2) and fire and storm (3). We created the other scenarios by building on the existing situation, incrementally

[5] The term "pathogen" includes diseases, parasitic attacks and fungi.

adding hazards: first pathogens (4), then drought (5), and finally both (6). We decided to consider pathogens and drought alongside the previous two hazards to determine whether there is a willingness to pay for these in addition to the hazards covered by current insurance contracts in France. It seems unlikely that insurers will decide to no longer cover the current hazards, which is why we are keeping storms and fires. However, we believe it is possible to consider covering new hazards, which is why we are adding drought and pathogens.

Secondly, the deductible rate refers to the share of the damage or loss that falls to the forest owner before the insurance begins to pay out.[6] This element is always included in forestry insurance contracts, and defines the percentage of damage at which the insurance begins to compensate the forest owner. This is a traditional way of reducing insurance premiums by shifting a part of the responsibility from the insurer to the insured (Mossin, 1968). This means that the higher the deductible level is the lower the premium should be. The three situations presented in Table 1 are currently possible in France depending on the insurance company.

Thirdly, the duration of the contract determines the period during which the forest is covered by the insurance. In general, the duration of the contract is one year. It is renewed each year on expiry for a further annual period. Some forest owners may seek out longer-term insurance contracts to guarantee ongoing and sustainable protection for their forest. Longer contracts may allow for more stable financial planning, while shorter contracts may offer more flexibility. Several studies have discussed the benefits of multi-annual insurance contracts in agriculture to protect against damages caused by weather-related events (Chen and Goodwin, 2015; Kunreuther and Michel-Kerjan, 2011). This 'duration' attribute has already been tested in the case of agricultural insurance in Doherty et al. (2021) using a DCE. The authors concluded that farmers prefer multi-year coverage to annual renewal. We can therefore easily assume that there may be a demand for multi-year contracts for forest owners, especially given the time horizon for forest growth.

Lastly, the monetary attribute represents the cost of insurance. It is an annual amount in euros per hectare. It represents the amount of money that the forest owner must pay to the insurer to maintain full insurance cover for one year. In the event of a claim, the insurance fully covers the damage. Of course, this is a simplified representation of what is found in conventional insurance contracts, since the insurance premiums paid often depend on the

[6] We gave an example to the respondent: "This concept is similar to that of the deductible in other types of insurance, such as car insurance. If the forestry insurance contract specifies an excess of, for example, X%, this means that the forest owner is responsible for covering the first X% of the damage or loss resulting from a claim. The insurance will cover costs in excess of this percentage excess."

age of the stand, the tree species, the location, and other specific features. The idea here is simply to observe the impact of a variation of this annual cost and then calculate the marginal willingness-to-pay for the various attributes. The literature reveals that the current situation in France ranges between €5/ha to €6.5/ha (Holecy and Hanewinkel, 2006; Wang et al., 2025).

3.1.2 Efficient design

The choice tasks for the DCE were generated using an updated experimental design optimised for D-efficiency with the Ngene software (Cho, 2021). It satisfies the orthogonality conditions, thus allowing an independent estimate of the influence of each design attribute on choice. The D-efficient design maximizes statistical efficiency (e.g., D-efficiency) by selecting choice sets that provide the most information for estimating model parameters. This type of design is specifically crafted to maximize the information obtained while minimizing the number of choices presented, thereby reducing cognitive load for respondents and enhancing the precision of econometric estimates. We constructed six choice tasks (or choice cards, i.e, 6 scenarios in which respondents had to choose between two insurance contract or no insurance).

To optimize the design, we used informative priors based on a preliminary pilot study (10% of the whole sample). These priors informed the distributions of the attribute coefficients, making the design more relevant and aligned with the preferences observed in the target population. This approach ensures that the scenarios presented to the participants are both realistic and statistically efficient, thereby strengthening the robustness of the results obtained.

Figure 2 below is an example of a choice card that the respondent faces and for which s/he must choose which option s/he prefers. Each choice card contained two insurance contracts and one ‘opt-out’ alternative. The inclusion of an opt-out option ensures that respondents are not compelled to select between two potentially undesirable alternatives that they would not realistically choose in practice (Lancsar and Louviere, 2008).

	Contract A	Contract B	Neither
Type of hazards covered	Fire + storm + pathogens	Fire + storm	-
Deductible rate (in %)	15 %	15 %	-
Duration of the contract (in years)	5 years	1 year	-
Annual cost of the insurance (in euros per hectare)	15 €/ha	25 €/ha	0 €
I would prefer:	○	○	○

Figure 2: Example of one of the six choice cards of the final choice experiment survey

4 Econometric modelling

For our econometric approach, we adopted a multi-stage econometric modelling approach. Here we are trying to estimate the probability of choosing an alternative in the presence of certain characteristics, focusing solely on the characteristics of the contract. We estimated multinomial logit (MNL) models to capture the general effects of the attributes on choice probabilities.

4.1 General theoretical framework

This study is grounded in two key theoretical frameworks: the Random Utility Theory (RUT) proposed by McFadden (1972) and the Lancaster Theory of consumer choice (1966). These theories provide the foundation for understanding how individuals make choices among discrete alternatives based on the utility derived from the attributes of those alternatives. Lancaster's Theory of consumer choice (1966), further enriches the analysis by emphasizing that consumers derive utility not from the goods themselves but from the characteristics or attributes those goods possess. According to this theory, each good can be seen as a bundle of attributes, and these attributes are directly influencing consumer's utility. More precisely, forest owner's decision to take out a forest insurance contract against natural hazards results from a comparison of the utility he derives from the different options available.

The Random Utility Theory posits that the forest owner's choice among a set of alternatives is driven by the utility they derive from each option. In a given sample with N respondents, each respondent will be confronted with S choice sets and each choice set has J alternatives.

The indirect utility for respondent n to choose alternative j in the choice set s is written as:

$$U_{njs} = V_{njs} + \epsilon_{njs}, \qquad j = 1, ..., J, s = 1, ..., S, \tag{1}$$

where V_{njs} is a deterministic component, which is a function of the observable attributes of the alternative (including a price attribute and the characteristics of the individual, and a stochastic component ϵ_{njs}, which captures unobserved factors.

Taking into account the rationality of individuals, given a set of alternatives, individual n will choose the alternative j that maximizes their utility. Therefore, respondent n will choose alternative i in the choice set s if this random utility U_{nis} is greater than the random utility U_{njs}:

$$U_{nis} \geq U_{njs}, \qquad \forall i, j \in s, i \neq j \tag{2}$$

Since only the choice preferred by the individual n is observed, we estimate the probability of the individual n choosing the alternative i for each choice set s based on random utility maximization. The probability of individual i choosing alternative j is then expressed as:

$$P_{ns}(i) = \Pr(\epsilon_{njs} - \epsilon_{nis} \leq V_{nis} - V_{njs}), \qquad \forall i, j \in s, i \neq j \tag{3}$$

where the new error term $\varepsilon_{njs} = \epsilon_{njs} - \epsilon_{nis}$ follows a logistic distribution, giving the choice probabilities: $p_{ns}(i) = \frac{\exp(\epsilon_{nis})}{\sum_{j=1}^{J} \exp(\epsilon_{njs})}$

In practice, the deterministic part V_{ij} is often modeled as a linear function of the attributes of the alternatives, allowing us to estimate the relative importance of these attributes in the decision-making process.

In the context of our study, this means that forest owners derive utility not from the insurance contracts themselves, but from specific characteristics of those contracts, such as the deductible level, cost, duration of the contract and hazard(s) covered. By combining the Random Utility Theory with Lancaster's approach, we can better understand the trade-offs that forest owners are willing to make between different contract attributes. Therefore, we can model the decision-making process of forest owners in a way that captures both the probabilistic nature of choice and the importance of individual contract attributes. The DCE methodology employed in this study is particularly well-suited for this purpose, as it allows us to estimate the relative importance of different attributes and predict the likelihood of various contract choices under different scenarios.

4.2 The multinomial logit model

We estimate a multinomial logit model, a simple and basic random utility model used to understand and predict choices in situations where several options are available in order to explain discrete choices (McFadden, 1972). It is an econometric approach widely used for discrete choice experiments. The MNL model estimates the probability of choosing a given alternative as a function of choice attributes and individual preferences. This model is particularly relevant to the study as it assumes that respondents evaluate each alternative independently and make decisions on the basis of utility derived from attribute levels. The MNL framework allows direct estimation and interpretation of the influence of each attribute on choice probabilities, making it an appropriate method for understanding how individuals arbitrate between risk, deductible, contract duration and cost when choosing insurance contracts.

For each choice set s, the probability of individual n choosing alternative i is:

$$p_{ns}(i) = \frac{\exp(X_{nis}\beta)}{\sum_{j=1}^{J} \exp(X_{njs}\beta)} \tag{4}$$

with the parameters β associated with the differences between the value of attributes for a given alternative and those of the attributes of the reference alternative called the status quo.

Although it has the advantage of being easy to calculate and interpret, its limitation is that it is based on the assumption of independence of irrelevant alternatives (IIA).[7] Hence, this type of model can yield inconsistent estimates and unrealistic substitution results between alternatives if this assumption is violated.

4.3 Willingness-to-Pay (WTP) estimation

To estimate a monetary value to attributes, we introduce WTP that can be elicited from choice experiment (Tokunaga et al., 2020). This is used to measure how much individuals

[7] The errors are independently and identically distributed, which means that the odds ratio between two alternatives does not change if another alternative is included or excluded.

would be willing to pay for a change in the characteristics of the insurance contract. In our choice models, WTP for a one-unit change in an attribute is calculated as the negative ratio of the attribute's coefficient to the cost coefficient:

$$WTP = -\frac{\beta_{attribute}}{\beta_{cost}} \tag{5}$$

with $\beta_{attribute}$ is the coefficient of a non-monetary attribute and β_{cost} is the coefficient of the monetary attribute.

To quantify the willingness-to-pay (WTP) for the modelled attributes, we used the Delta method, which approximates the standard errors of functions of estimated parameters (Daly et al., 2023). This approach facilitates robust statistical inference on the WTP estimates, enabling hypothesis testing and the construction of confidence intervals to assess their significance.

5 Empirical results

5.1 Database and sample characteristics

We have performed a data cleanup on the original database [8] and we implemented several measures to mitigate potential biases. First, we excluded observations where response times were less than 40% of the median, commonly referred to as "speeders". Second, respondents who answered the filter and attention questions incorrectly were automatically excluded from the questionnaire, and had no opportunity to re-open it.[9] The survey was opened by 1098 respondents, including 760 incomplete questionnaires. After cleaning, the final database includes 317 respondents.

After that, we prepared the data, including the encoding of non-numerical variables. This ensured that the data was in the appropriate format for analysis. Tables 4, 5 and 6 in Appendix A present the descriptive statistics from the sample based on the demographic profile of the

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

[9] The filter question at the beginning of the questionnaire allows us to eliminate respondents who are not forest owners. The attention question comes just after the DCE: "Imagine a forest with several footpaths. Trail A is 15 kilometers long, trail B is 20 kilometers long and trail C is 22 kilometers long. What is the total length of the trails in this forest?" with 4 possible answers (55 kilometers, 60 kilometers, 57 kilometers, 52 kilometers). Respondents who gave incorrect answers were automatically excluded from the questionnaire.

forest owner and forest characteristics. We can see from the first table that in our sample, the majority are men aged over 45 years. They are characterized by a relative risk aversion coefficient of 0.76, indicating that they are "very risk averse". Forest ownership in France is rarely a main professional activity (Agreste, 2014), private forest owners belong to various socio-professional categories, such as retirees, farmers, employees, professionals, intermediate professions and senior executives. In terms of the educational profile, approximately 35% of forest owners have a Master degree, while 14% have a general or technological baccalaureate. 69% of respondents declared an income of over €3,000. Survey respondents are forest owners with small forest areas: 39.1% have more than 4 and less than 10 ha and 37.3% have less than 4 ha. For the most part, they own forests through heritage (60.9%). The majority of forest owners have owned their forests for more than 15 years (42.9%). In our sample, forest owners declare that they have no forest certification at 46.1%. They are represented throughout France, mainly in Grand-Est region (16.7%), the south-west (Nouvelle Aquitaine, 13.1%) and in the Auvergne-Rhône Alpes region (14.8%). The geographical dispersion of the respondents is presented in Fig. 4 in Appendix B. Concerning the forest composition, mainly private forests in the sample are a mix of coniferous and deciduous stands or predominantly deciduous. In terms of choice distribution, 35.28% chose contract A, 37.22% contract B and 27.5% no contract.

5.2 Econometric analysis

5.2.1 Forest owners' decision to take out an insurance policy

For the econometric analysis, we used the Apollo package on R for analysis and econometric estimation (Hess and Palma, 2019), and we estimated parameters using a Multinomial Logit (MNL) model.

Let U_{ij} denote the utility that individual i derives from choosing alternative $j \in \{1, 2, 3\}$, where $j = 1$: Contract A, $j = 2$: Contract B, $j = 3$: Opt-out (no insurance), the utility function is specified as follows:

$$U_{ij} = ASC_j + \beta_{\text{storm}} \cdot \text{storm}_{ij} + \beta_{\text{drought}} \cdot \text{drought}_{ij} + \beta_{\text{pathogen}} \cdot \text{pathogen}_{ij} + \beta_{\text{deductible}} \cdot \text{deductible}_{ij} + \beta_{\text{duration}} \cdot \text{duration}_{ij} + \beta_{\text{cost}} \cdot \text{cost}_{ij} + \varepsilon_{ij} \quad (6)$$

We included three alternative-specific constants (ASCs), allowing the two choice scenarios to be considered separately, with the ASC for the opt-out option set to 0. This controls for potential order effects, i.e. where the position of alternatives in a choice task influences respondents' decisions (Boxebeld, 2024; Cao et al., 2018).

To model the attribute related to the hazards covered by the insurance contract, we adopted a dummy variable approach. Each alternative in the choice set was associated with a specific combination of covered hazards, ranging from single to multiple risks.

This attribute consisted of six levels: (1) fire, (2) storm, (3) fire and storm, (4) fire, storm, and pathogens, (5) fire, storm, and drought, and (6) all hazards. In the dataset, each level was coded as a categorical variable and subsequently transformed into a set of binary (dummy) variables to be used in the econometric analysis. Specifically, for each alternative, a dummy variable took the value 1 if the insurance option covered the corresponding set of hazards, and 0 otherwise. The level ("fire only") was omitted in the estimation as the reference category to avoid multicollinearity.

The deductible rate, the duration of the contract and the annual cost are coded as a continuous variable.

Variable	Estimate	Rob standard errors
ASC_{alt1}	0.204	0.608
ASC_{alt2}	0.260	0.598
Storm	-0.079	0.126
Fire & Storm	0.551*	0.331
Fire & Storm & Pathogens	0.410***	0.122
Fire & Storm & Drought	0.093	0.200
All hazards (Fire, Storm, Pathogens, Drought)	0.950***	0.262
Deductible	-0.168***	0.036
Duration	0.163	0.171
Cost	-0.081*	0.042
Model information		
Estimation method	bgw	
n individuals	317	
n choice situations	1902	
Log-likelihood at equal shares, LL(0)	-2089.56	
Log-likelihood (final)	-2014.74	
Rho^2 vs equal shares	0.0358	
Adj. Rho^2 vs equal shares	0.0310	
Rho^2 vs observed shares	0.0286	
Adj. Rho^2 vs observed shares	0.0247	
AIC	4049.47	
BIC	4104.98	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors reported.

Table 2: Estimation results from the Multinomial Logit model

The econometric results of the DCE in the Table 2 reveal several significant preferences regarding insurance contract features.

Alternative-specific constants (ASC) are positive but not statistically significant. This indicates that, when no attribute information is provided, respondents do not exhibit a significant inherent preference for the insurance alternatives (alt1 or alt2) over the status quo (no contract). In other words, the choice of an insurance contract is primarily driven by its specific characteristics rather than a general tendency to prefer insured options.

The coefficient associated with *Storm* ($\beta = -0.079$) is not significant, suggesting that offering coverage for storm damage alone does not significantly influence the likelihood of choosing an insurance contract, compared to the reference level (fire only).

In contrast, some multi-hazard coverage options significantly affect preferences. The coefficient for *Fire & Storm* ($\beta = 0.551$, $p < 0.10$) is positive and weakly significant, indicating a modest increase in utility when both fire and storm risks are covered. The coefficient for *Fire & Storm & Pathogens* ($\beta = 0.410$, $p < 0.01$) is highly significant and positive, showing that respondents clearly value the inclusion of pathogen hazards in the coverage. Similarly, the coefficient for the most comprehensive option, *All hazards* ($\beta = 0.950$, $p < 0.01$), is large and strongly significant, suggesting that forest owners place the highest value on insurance policies providing broad protection against multiple hazards. By contrast, the coefficient for *Fire & Storm & Drought* ($\beta = 0.093$) is not significant, indicating that adding drought coverage alone does not substantially alter preferences.

As expected, the coefficient associated with *Deductible* ($\beta =$ -0.168, $p < 0.01$) is negative and significant, meaning that higher deductibles reduce the attractiveness of the insurance contracts. Forest owners prefer contracts with lower deductibles, reflecting a desire to limit their financial responsibility in case of damage. The coefficient for *Duration* ($\beta = 0.163$) is not statistically significant, suggesting that contract length does not affect choice in this model.

Finally, the results show that respondents are sensitive to cost (*Cost* ($\beta = -0.081$, $p < 0.10$)), systematically preferring less expensive coverage, underlining the importance of affordability in influencing their choices.

Among the statistically significant attributes, the most substantial effect is associated with comprehensive coverage (*All hazards*), followed by pathogen coverage. This indicates that broader and more inclusive risk protection provides the greatest increase in perceived utility. However, to better compare the relative importance of these attributes, willingness-to-pay (WTP) measures should be computed.

5.2.2 Forest owners' willingness to pay for insurance contract characteristics

To provide a monetary interpretation of respondents' preferences, the marginal willingness-to-pay (WTP) for each attribute was derived using the delta method based on the estimated coefficients. The WTP values represent the amount respondents are willing to pay per hectare (in euros) for a given change in the attribute, relative to the contract cost. The WTP estimates (Table 3) provide insight into the monetary valuation of the contract characteristics.

WTP	**Estimate**	**Standard Error**
WTP_storm	-0.9705	1.6061
WTP_fire_storm	6.7921	7.2465
WTP_fire_storm_pathogen	5.0536*	3.0585
WTP_fire_storm_drought	1.1413	2.0844
WTP_all_hazards	11.7157	8.7481
WTP_duration	2.0036	3.0070
WTP_deductible	-2.0726**	0.9278

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Standard errors are calculated using the Delta Method with the robust variance-covariance matrix.

Table 3: Willingness-to-pay (WTP) estimates

The WTP for *Deductible* is negative and significant ($\text{WTP}_{deductible} = -2.07$, $p < 0.05$), indicating that respondents are willing to pay approximately €2.1 more per hectare to reduce the deductible by one unit. This confirms that forest owners prefer insurance contracts that minimize their own financial exposure in the event of damage. This means that the current situation on the French insurance market with regard to contract duration aligns with the expectations of forest owners. It also suggests that contracts with lower deductibles should currently be the most popular option on the market.

Respondents are willing to pay around €5.1 more per hectare for policies covering *Fire, Storm, and Pathogens*, and approximately €11.7 more per hectare for fully comprehensive coverage (*All hazards*), although not statistically significant. These positive values reinforce the qualitative finding that forest owners value broader protection and, in particular, pathogen-related coverage.

The fact that the estimate for storm is insignificant and close to 0 could be related to the fact that current insurance contracts in France all offer the storm+fire package. This may also be related to the fact that the previous storm is "far" in France (i.e., 2009) whereas the other hazards (fire, droughts and pathogen attacks) are the current problems. These results suggest that insurance products that include protection against pathogens and drought are likely to be the most attractive. The major intuition here is that there is a positive willingness to pay on the part of forest owners for hazards that are not yet covered by current insurance policies. This highlights the mismatch between the existing contracts and forest owners' expectations.

The Fig. 3 shows these results graphically, representing the estimated WTP for each attribute included in the DCE, along with 95% confidence intervals. This graph shows the negative and significant WTP for the attribute related to the deductible, as well as a positive and significant WTP for the Fire, Storm, Pathogens hazard package.

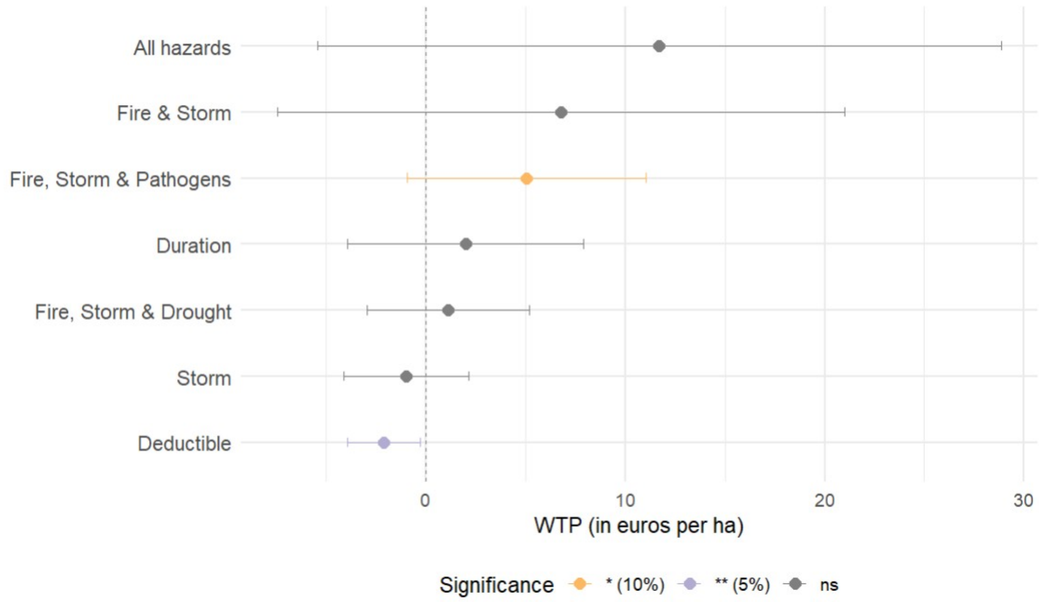

Figure 3: WTP estimates with 95% Confidence Intervals

6 Discussion

This article aims to understand the forest insurance preferences of private forest owners and to study the factors that influence the adoption of forest insurance in a climate change context. This study aimed to address a huge gap in the literature on forest insurance adoption, by identifying determinants of forest insurance demand coming from the supply side of the insurance markets and linked to the characteristics of the insurance contract.

Using a DCE, we were able to define the key elements involved in forest owners' decision-making when it comes to choosing forest insurance against natural hazards. The results also show that private forest owners pay particular attention to some of the attributes tested: the type of hazards covered, the deductible level, and the annual cost of the insurance. An important result is that forest owners are not willing to pay for storm insurance (in addition to fire). On the other hand, they are willing to pay for the package "Fire-Storm-Pathogens", and even more so for the "all hazards" package (Fire, Storm, Pathogens, Drought). This means that French private forest owners want to include Pathogens in insurance contracts, unlike Drought without Pathogens. Interestingly concerning pathogens, emerging and possibly fast-growing hazards, this result is probably linked to the recent invasion of various pathogens in France, particularly bark beetles in the north-eastern and south-western regions of France. Widespread media coverage of the damage has raised awareness among private forest owners and demonstrated their willingness to pay for pathogen coverage in this DCE. This result also expresses a mismatch between the current offer and the real needs.

Particular attention will be paid to the question of how to adapt insurance products and the market to the intensification of hazards and the emergence of new hazards linked to climate change. Our results suggest to avoid covering storm in addition to fire but more to focus on new emerging hazards. In addition, our results indicate that keeping deductible as lower as possible may encourage the adoption, as well as providing one-year contract. Some of these changes require to increase the insurance premium so that trade-offs should be find. This also raises the question of the role of government authorities and the incentives they provide. Our results reveal that the private forest owners are very sensitive to the cost of the insurance premium and a way to reduce may be to subsidize the insurance premium, as already done in France for agricultural insurance. There is also the question of the role of the government, which wants forest owners to insure their assets more fully and effectively against storms and fires. To this end, the tax benefits of the "DEFI Assurance" scheme allow forest owners who insure their forests to receive a tax credit of 76% of eligible storm and fire premiums, below the ceiling of €15 per hectare. In return, forest owners must provide proof that their land is insured against the risk of storms or fires. They must therefore provide an insurance certificate specifying the number of hectares covered for the current fiscal year. Despite the introduction of this subsidy, insurance uptake in France has not increased, so it seems important to consider a more effective incentive, combined with more suitable insurance policies.

Areas recently affected by major events, such as in south-west of France, will provide a good example of the challenges facing public policy-makers and insurance companies at the regional and local levels.

This study proposes hypothetical insurance scenarios but without taking care of their "feasibility", that can be seen as a first limitation. In practice, insurers may not be in a position to offer multi-year contracts, or to insure against drought and pathogen risks. Although we have identified strong interest in certain types of cover, implementing insurance solutions for specific hazards, such as drought or pathogen, could prove particularly difficult in practice. The reason is that drought and pathogens are often linked to another hazard occurrence such as a storm or fire, and this correlation makes it difficult for insurers to calculate premiums. It should be noted that this raises questions about one of the criteria for insurability: the independence of risks. This underlines the complexity of designing viable insurance products for such interdependent risks. However, we remark that other countries are able to provide such a protection against pathogens like Finland [10], meaning that it will be feasible in some cases.

Parametric or index-based insurance could overcome some of these problems, as it relies on predefined indices (e.g. precipitation thresholds) rather than direct loss assessments. However, the feasibility of this approach in the context of forests is not yet widely studied, because of the complex dependencies between climatic variables and forest ecosystems and the complexity to establish the causal link between the observed damage and the occurrence of a precise natural event. Brèteau-Amores et al. (2021) provided a first attempt in this direction by studying index insurance to cover drought event in French forest.

Future research should aim to bridge the gap between demand and supply, exploring innovative insurance mechanisms that reconcile affordability for forest owners and viability for insurers.

7 Acknowledgements

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[10]The Finnish insurance company 'Pohjola Insurance' covers damage caused by insects and fungal diseases.

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A Tables presenting descriptive statistics

Category	% of the sample (n=317)
Area	
Less than 4 ha	37.3%
More than 4 and less than 10 ha	37.5%
More than 10 and less than 25 ha	13.3%
More than 25 and less than 100 ha	10.7%
More than 100 ha	2.2%
Total	**100%**
Forest Ownership	
By purchase (yes)	36%
By heritage (yes)	60.9%
By donation (yes)	8.2%
By planting (yes)	2.2%
Regional location	
Auvergne - Rhône-Alpes	14.8%
Bourgogne - Franche-Comté	7.9%
Bretagne	3.8%
Centre - Val de Loire	6%
Corse	1.3%
Grand-Est	16.7%
Hauts-de-France	5.4%
Ile-de-France	5.7%
Normandie	3.2%
Nouvelle-Aquitaine	13.9%
Occitanie	10%
Pays de la Loire	3.5%
Provence Alpes Côte d'Azur	7.6%
I don't want to answer	0.3%
Total	**100%**
Since forester	
Since less than 5 years	12.6%
Since 5-10 years	20.2%
Since 10-15 years	23.4%
More than 15 years	42.9%
I don't know	0.9%
Total	**100%**
Forest Composition	
Predominantly coniferous	12%
Predominantly deciduous	41%
A mix of coniferous and deciduous stands	45.7%
I don't know	1.3%
Total	**100%**
Certification	
Yes, PEFC	17.3%
Yes, FSC	9.8%
No	46.7%
I don't know	26.2%
Total	**100%**

Table 4: Descriptive statistics: Part 1 of the questionnaire

Category	**% of the sample (n=317)**
Are insured	39.1%
Have been confronted with natural hazards impacting their forest in the last 5 years	18.3%
For those answering yes to the previous question...	
...Fire	25.9%
...Storm	77%
...Snow	5.2%
...Frost	3.4%
...Pathogens	17.2%
...Hail	6.9%
...Other: Flooding	1.7%
Knowledge of forest insurance	mean = 2.52 sd = 1.05

Table 5: descriptive statistics: Part 4 of the questionnaire

General Category	% of the sample (n=317)
Genre: Male	70%
Has children	91.2%
Married	85.5%
Average relative risk aversion coefficient	0.76
Age Category	
Less than 25 years	0.3%
25-34 years	0.9%
35-44 years	3.5%
45-54 years	46.1%
55-64 years	26.2%
65-74 years	20.2%
More than 75 years	2.8%
Total	**100%**
Professional Categories	
Farmers	6.9%
Craftsmen, retailers	1.9%
Executives and higher intellectual professions	53.7%
Employees	2.5%
Intermediate occupations	4.4%
Retired	29.7%
Total	**100%**
Education Level	
General or technological baccalaureate	14.2%
BETC Higher National Diploma	20.8%
PhD	3.2%
BA	19.9%
MA	35.3%
Other	6.6%
Total	**100%**
Income	
Less than €1000	0.4%
From €1000 to €1500	0.9%
From €1500 to €2000	4.4%
From €2000 to €2500	7.6%
From €2500 to €3000	13.9%
More than €3000	69.1%
I don't want to answer	3.8%
Total	**100%**

Table 6: Descriptive statistics: Part 5 of the questionnaire

B Geographical dispersion of the respondents

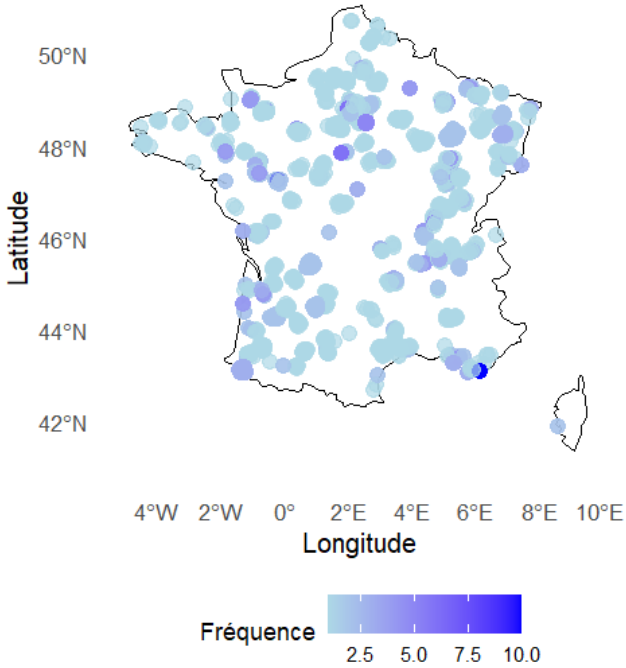

Figure 4: Geographical dispersion of French respondents