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# Perception of (multi)risk in forest: a review of the literature

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## Abstract

Forests provide a wide range of goods and services that are threatened by natural disturbances, which represent one of the greatest threats to forests worldwide. Climate change increases their frequency and intensity, creating a multirisk context in which different hazards act in combination. How forest owners perceive these interconnected risks is crucial for the implementation of adaptation strategies and the development of relevant public policy. In this article, we conduct a literature review examining how existing articles address risk perception in forests, particularly in relation to multirisk. Our review focuses exclusively on research articles written in English, with at least one keyword for risk perception, forests, and risk. More specifically, we examine whether the methodologies used to study isolated risks remain relevant when considering multirisk. Our main conclusion is that no study directly addresses the perception of multirisk in forests, as almost all the articles consider risks in isolation. Methodologically, most studies rely on surveys conducted among professionals, forest owners, or local residents. Very few articles are theoretically grounded or based on economic models. In addition, the literature reveals a lack of diversity in both the risks and countries studied, with the majority of papers focusing on wildfires in the United States. Therefore, understanding the perception of multirisk in forests remains a broad field for future research, both theoretically - particularly in economics - and empirically, through further exploration of underrepresented countries.

**Keywords:** Forest; Risk; Perception; Multirisk; Review; Cognitive

**JEL Codes:** D83, D91, Q23

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# 1. Introduction

Forests are of critical importance as they provide a wide range of goods and services, including wood and non-wood products, biodiversity, soil and water protection, social benefits, and carbon storage (FAO 2020). Demand for these continues to grow, particularly in Europe, where wood supply exceeds 550 million m<sup>3</sup> per year (FOREST EUROPE 2020). However, forests are increasingly exposed to natural disturbances that, although contributing to forest dynamics and regeneration at small scales (European Environment Agency 2023), also threaten forest health and ecosystem services.

Recent decades have been marked by increasing frequency and intensity of natural disturbances worldwide (Schelhaas et al. 2003; Van Aalst 2006), largely driven by climate change (Seidl et al. 2011). At the European scale, Patacca et al. (2023) report significant increases in forest disturbances from 1950 to 2019, amounting to 43.8 million m<sup>3</sup> of disturbed timber annually, equivalent to 16% of the European Union's yearly harvest. Climate change also intensifies interactions between disturbances (Bastit et al. 2023; Gallina et al. 2016; Seidl et al. 2017; Susaeta et al. 2014). These interacting risks, referred to as "multirisk," are defined by Curt (2021) as "a set of different hazards able to act in combination, with or without coincidence over time and impacting, in a given territory, potentially dependent stakes." This perspective considers risks as interconnected, cascading, and non-linear phenomena rather than isolated events (Agne et al. 2018; Buma 2015; Sieg et al. 2017; Simpson et al. 2021). For example, warmer temperatures and altered precipitation increase drought stress, weakening tree defenses and raising vulnerability to bark beetles (Brunette et al. 2025; Ruzzier et al. 2023; Singh et al. 2024). Reduced precipitation further accelerates bark beetle development and infestation pressure (Jakoby et al. 2019; Lindelöw and Martin 2007). Such cascading effects may generate losses greater than the sum of individual events (Venäläinen et al. 2020), increasing economic costs, timber losses, and degradation of ecosystem services (FAO 2023). These impacts affect a broad range of stakeholders, including forest owners, forestry companies, NGOs, public authorities, forest users, and local residents.

Ensuring the long-term viability of the forestry sector therefore requires more integrated management approaches accounting for interconnected disturbances (Potter et al. 2019). Yet multirisk complicates decision-making because interactions between hazards remain difficult to quantify. Risk perception consequently becomes a key factor in forest adaptation to climate change (McFarlane et al. 2006), defined as "the subjective judgment that people make about the characteristics and severity of a risk" (IPCC 2023a). Understanding how stakeholders perceive and construct risks is thus essential for sustainable forest management, as perceptions influence management priorities, adaptation strategies, preventive measures, and long-term planning. In this context, we address the following question: to what extent are existing approaches to forest risk perception relevant for addressing the challenge of multirisk? More specifically, we examine how risk perception is studied in forestry literature, how multirisk is addressed, and whether approaches developed for single risks remain suitable for multirisk perception in forests.

Numerous literature reviews have examined forest risks, their interactions, and their biophysical determinants. Several studies synthesize the mechanisms through which disturbance agents interact and amplify forest damages. For example, Jenkins et al. (2014) show that bark beetle infestations and forest fires are closely linked, increasing both the likelihood and severity of damages. Similarly, Singh et al. (2024) highlight the relationship between bark beetles and climate change, while Bastit et al. (2023) review interactions among multiple forest risks. These contributions are essential for understanding forest dynamics under multiple hazards, but they mainly focus on ecological and biophysical dimensions rather than on how risks are perceived and interpreted by stakeholders.

At the same time, a body of literature on risk perception has developed across psychology, decision sciences, and environmental studies. Foundational works demonstrated that risk perception depends not only on statistical probabilities but also on affective, cognitive, social, and cultural factors (Slovic 1987; Tversky and Kahneman 1974). More recent syntheses, such as Siegrist and Árvai (2020), identify three broad categories shaping risk perception: characteristics of the risk itself, characteristics of individuals, and cognitive heuristics. While this framework provides a strong conceptual basis, it remains largely detached from applied environmental contexts

such as forestry, where long temporal horizons and uncertainty strongly shape perceptions.

In forestry and environmental studies, risk perception is also linked to concepts such as concerns, worries, or perceived threats expressed by forest owners and stakeholders. Hall et al. (2022) conducted a systematic review of studies on wildfire risk perception among households in forest-urban interfaces and proposed a scale measuring dimensions such as perceived likelihood, severity, emotional responses, and preparedness behaviors. Although this work synthesizes empirical findings, it remains limited to a single hazard. Likewise, McCaffrey (2004) review individual responses to wildfire risk to inform prevention and management policies, while Klapwijk et al. (2016) examine how public awareness can support the prevention and eradication of pests and pathogens. Other approaches treat forest risk more conceptually. Blennow et al. (2014) review different concepts of risk related to forest ecosystem services and discuss their implications for management and planning. Although they introduce elements related to perception, such as heuristics and confidence, they do not systematically analyze empirical studies on forest risk perception.

Finally, several reviews examine broader social and psychological factors influencing risk perception, including trust (Siegrist 2021), place attachment (Bonaiuto et al. 2016), and emotions in climate risk assessment (Brosch 2021). However, these studies neither focus specifically on forests nor address interactions among multiple hazards.

Overall, the literature includes numerous syntheses on forest risks and extensive work on risk perception and its determinants. Some studies address perceptions of forest risks, but they focus mainly on isolated hazards. To date, no literature review has examined how stakeholders jointly perceive multiple interacting forest risks within a multirisk context.

Consequently, this article addresses this gap through a systematic literature review of studies on risk perception in forestry contexts. The review includes both studies examining single forest-related risks and those addressing multiple risks simultaneously. By considering this spectrum of research, we identify how multirisk perception is conceptualized, explicitly or implicitly, and assess whether existing studies capture the interconnected nature of risks in forestry systems. To this end, we analyze the risks addressed in the literature, identify remaining research gaps, and examine the methodologies used to study risk perception and multirisk.

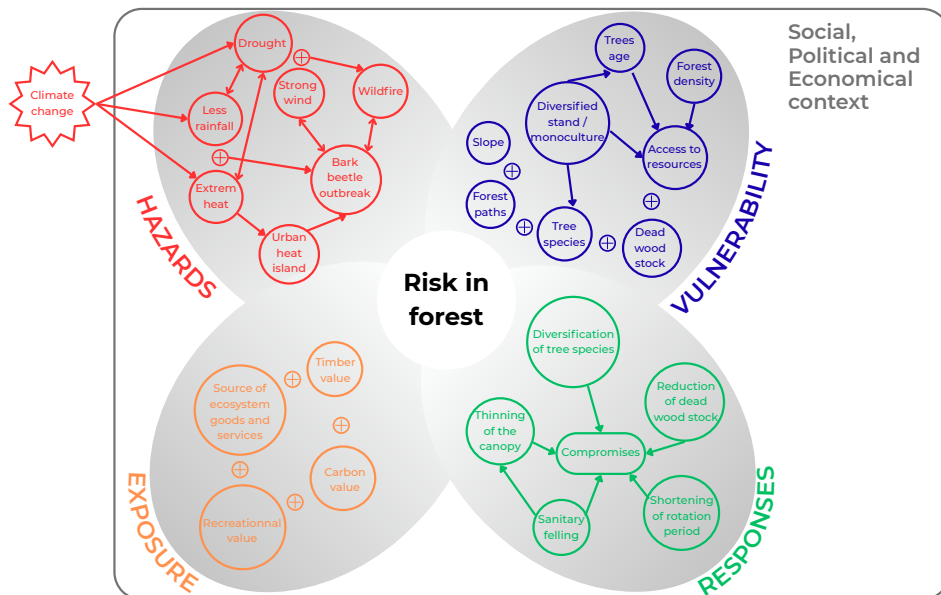
This work contributes to broader efforts to understand forestry decision-making under climate change. Our findings show that no study directly addresses multirisk perception in forests, as most papers consider risks in isolation. Methodologically, the literature relies mainly on surveys conducted among professionals, forest owners, and local residents. Few studies are theoretically grounded. As a result, understanding multirisk perception in forests remains a major research challenge, both theoretically, especially in economics, and empirically, through greater attention to understudied countries and risks.

The rest of the paper is organized as follows. Section 2 presents the materials and methods used for the literature review. Section 3 presents the results of the analysis, while Section 4 discusses them. The conclusion is provided in Section 5.

## **2. Materials and method**

### **2.1. Key concept: risk and multirisk in forests**

Following the classical distinction proposed by Knight (1921), risk refers to situations in which the probability and consequences of an event can be estimated, unlike uncertainty, where probabilities remain unknown. In the context of climate change, risk results from interactions between hazards, exposure, vulnerability, and responses implemented to address them (IPCC 2023a, 2023b). In forestry, as presented in Figure 1, hazards include disturbances such as wildfires, storms, droughts, or pest outbreaks; vulnerability refers to forests' susceptibility to these disturbances; exposure concerns affected ecosystem services, people, or assets; and responses encompass management actions such as thinning or modified rotation periods.



**Figure 1.** Multirisk profile for forests, adapted from the IPCC risk framework (IPCC 2023b).

The concept of multirisk is defined by Curt (2021) as "a set of different hazards able to act in combination, with or without coincidence over time and impacting, in a given territory, potentially dependent stakes." Several categorizations distinguish interactions between risks, including independent, compounding, cascading, and interconnected risks (Buma 2015; Gallina et al. 2016; Simpson et al. 2021). In forests, multirisk refers to interacting hazards affecting the same area, often through cascading effects.

For example, storms and snow damage in the European Alps create favorable conditions for bark beetle outbreaks (Wermelinger 2004), which subsequently increase deadwood accumulation and fire risk (Jenkins et al. 2014). Climate change further amplifies drought and fire frequency (Mutterer et al. 2025), while warmer temperatures and longer growing seasons facilitate bark beetle expansion into higher elevations and new host species (Bebi et al. 2017; Gerberding and Schirpke 2025).

Historical forest management can also intensify multirisk. Since the 1950s, many European regions have promoted dense, even-aged conifer monocultures to maximize profits (Spiecker et al. 2004), increasing forests' vulnerability to drought, storms, and bark beetle outbreaks (Mutterer et al. 2025; Seidl et al. 2011). Higher stand density strengthens competition for resources, worsening drought stress and fostering infestations (Singh et al. 2024).

Several approaches aim to integrate multirisk management into forestry, including disturbance monitoring, probabilistic modelling, adaptive silviculture, diversification of species and stand structures, and early detection systems (Brunette et al. 2025; Gallina et al. 2016; Mutterer et al. 2025; Singh et al. 2024). However, foresters frequently face trade-offs between competing objectives. For instance, sanitary felling may reduce bark beetle spread but increase wind vulnerability along exposed edges (Singh et al. 2024), while leaving deadwood can preserve avalanche protection but raise fire risk (Mutterer et al. 2025). Multirisk therefore goes beyond multiple independent events and encompasses interacting vulnerabilities, exposures, and management responses (Figure 1).

## 2.2. Theoretical anchorage of risk perception

An agent's behaviour toward risk is shaped both by the objective characteristics of hazards and by the subjective probabilities individuals assign to them (Kast 2002). In decision theory, risk refers to an uncertain event for which a probability can be assigned (Knight 1921). In forestry, risk assessment has traditionally relied on objective indicators such as historical records, hazard magnitude, frequency, and spatial distribution (Burton and Kates 1963). Within this framework, agents are assumed to know the probability distribution of possible

outcomes and to choose the option that maximises expected utility according to stable preferences (von Neumann et al. 1944; Kast 2002).

However, empirical evidence shows that forest owners and managers do not behave as fully rational agents in risk-related decision-making. Risk is not only a physical phenomenon but also a social construct shaped by beliefs, experiences, heuristics, and social interactions (Coppola 2015; Fischer et al. 2013; Sullivan-Wiley and Short Gianotti 2017). Moreover, Kangas and Kangas (2004) underline that the assumption of objective probabilities is often unrealistic in forestry, where uncertainty frequently prevails over measurable risk. Risk perception therefore plays a central role in management decisions. This perspective is rooted in the psychometric paradigm (Slovic 1987), which highlights the influence of psychological dimensions and hazard attributes on perceived risk.

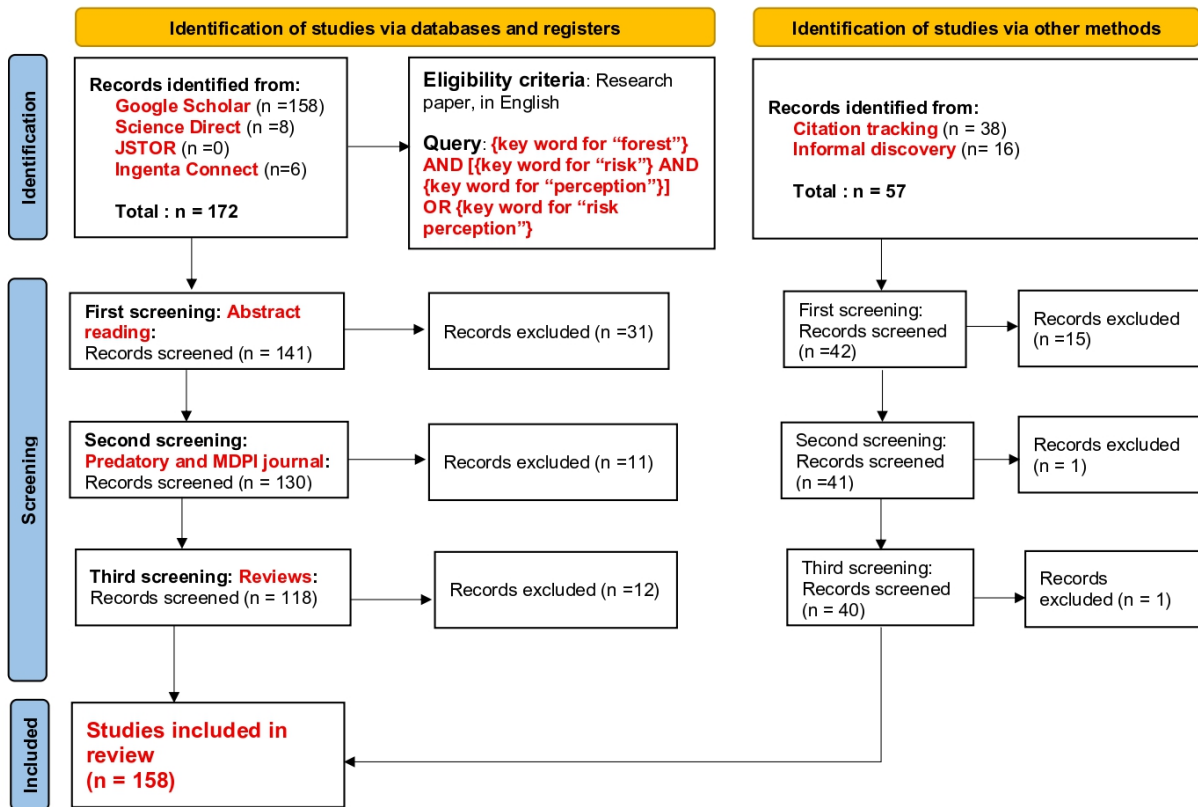
Many determinants of risk perception have been identified. Socioeconomic and demographic factors such as age, gender, income, and education significantly affect perceived risk levels (Siegrist and Árvai 2020; Flynn et al. 1994). Individuals with fewer financial resources, for example, often perceive higher risks because they feel less control over their environment (Collins 2012). Cognitive and cultural factors—including values, beliefs, memory, and political views—also shape how hazards are interpreted (Tanner 2022). Personal experience is especially influential: exposure to hazardous events tends to increase perceived risk and strongly affects beliefs (Champ et al. 2013; Martin et al. 2007; Sullivan-Wiley and Short Gianotti 2017). Similarly, Hertwig et al. (2004) show that personal experience often outweighs statistical information in shaping climate change perceptions.

Risk perception is further influenced by cognitive heuristics and biases. Because individuals have limited cognitive resources, they rely on simplifying heuristics that can distort judgments (Slovic et al. 1979). The availability heuristic, for instance, leads people to overestimate rare but memorable events and underestimate frequent ones (Slovic et al. 1979; Martin et al. 2007). Other biases, such as overconfidence and certainty bias, encourage individuals to favour familiar or seemingly “safe” options, even when inaction increases long-term risk (Kahneman and Tversky 1979). In forestry, refraining from prescribed burning may therefore appear safer despite increasing future wildfire risk (Maguire and Albright 2005).

Expected utility theory is also poorly suited to decisions involving high-impact, low-probability events or situations characterised by imprecise probabilities (Villacis et al. 2021). Climate change further complicates risk assessment by introducing new and evolving hazards, such as bark beetle outbreaks or drought-induced forest decline (Vitasse et al. 2023). In response, alternative approaches have emerged. Building on bounded rationality (Simon 1955), Prospect Theory (Kahneman and Tversky 1979) argues that individuals evaluate outcomes relative to a reference point and exhibit strong loss aversion. Empirical studies show that this framework better explains behaviour under climate-related risks, particularly through probability weighting and status quo bias (Bocquého et al. 2014; Villacis et al. 2021). More broadly, linking objective assessments with subjective perceptions has encouraged holistic approaches to risk analysis (Parkins and MacKendrick 2007). Understanding behaviour under risk therefore requires combining insights from economics and psychology, with risk perception playing a central role.

### **2.3. Methodological process**

This systematic review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, an internationally recognized framework for transparent reporting of review objectives, methods, and results. PRISMA enhances rigor, reproducibility, and comparability while reducing bias in the selection and synthesis of studies (Page et al. 2021). The methodological process, illustrated in the PRISMA flow diagram (Figure 2), applies two eligibility criteria: included documents must be peer-reviewed scientific articles written in English. The bibliographic search was conducted across four online databases: Google Scholar, ScienceDirect, JSTOR, and Ingenta Connect. These databases were selected for their complementary coverage of interdisciplinary literature in environmental sciences, economics, and social sciences. Google Scholar ensured broad academic coverage, while the other databases provided access to peer-reviewed and discipline-specific journals.



Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

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**Figure 2.** Flow diagram PRISMA.

Article selection was based on a structured query formulated as follows: (keyword for *forest*) AND [(key-word(s) for *risk*) AND (keyword(s) for *perception*)] OR (keyword(s) for *risk perception*). Keywords related to *risk* were drawn from Bastit et al. (2023), which addresses multiple forest hazards, including *risk*, *catastroph*<sup>1</sup>, *damage*, *mortality*, *disturbance*, *hazard*, *stochastic*, *uncertainty*, *interaction*, *cascad*\*, *multi-risk/multiple risks*. Keywords associated with *perception* or *risk perception* were identified through preliminary reading of papers on forest risk perception, including *perception*, *subjectiv*\*, *judgment*, *awareness*, *belief*, *preference*, *understanding*, *cognitive*, *feel*, *assessment*.

A total of 244 queries were identified. After adding references found through citation tracking and informal discovery, articles were screened in three stages: (1) abstract screening, retaining only papers examining risk perception in forestry contexts; (2) exclusion of predatory journals listed by Jeffrey Beall and MDPI journals to ensure scientific rigor and credibility; and (3) filtering by article type, excluding literature reviews, commentaries, and perspectives to maintain a focus on primary research. The final database included 158 research papers, listed in Appendix A.

## 2.4. Data extraction and study variables

We extracted a set of variables to assess whether and how multirisk perception is addressed in the forest risk perception literature (Table 1). The complete review database is available online.<sup>2</sup>

<sup>1</sup>The asterisk (\*) is used as a truncation operator to capture all words sharing the same root

<sup>2</sup>Barrey, Clémence; Brunette, Marielle, 2026, "Literature Review Data – Perception of multirisk in forests", <https://doi.org/10.57745/7IRZKT>, Recherche Data Gouv, V1

**Table 1.** Study variables.

	<b>Variables</b>	<b>Description</b>
Article reference	Authors	Name of all authors
	Country 1	Country of the first author of their affiliated institution
	Discipline 1	Discipline(s) of the first author
	Study Country	
	Keywords	Keywords provided by the authors on the title page and index keywords
	Year	Year of publication
	Journal	Name of the publication journal
Risks studied	Risk context	Natural hazards / Climate change / Others
	Type of natural hazards	Wind / Wildfire / Insects / Other
	Risks interaction	0 / 1
Methodological framework	Nature of the method	Qualitative / Quantitative / Mixed
	Methodological approach	Theory-driven study / Empirical
	Econometric model	0 / 1
Research protocol	Type of actor	Public forestry professionals / Private forest owners / Private forestry professionals / Local residents / General public / Visitors / NGOs / Scientists / Other
	Data collection	Structured & Semi-structured interview / In-depth interview / Closed-ended questionnaire / Open-ended questionnaire / Focus group / Experimental economics / Other
	Mode of administration	In-person / Mail / Phone / Online / Paper based
	Sample size	Number of people interviewed or studied
	Scale	Local / Regional / National / Transnational
	Investigation method	Longitudinal / Cross-sectional
	Studied variables	List of variables used in the method
	Data type	Binary variables / Categorical variables / Continuous variables / Likert scale / Multiple choice / Other scale / Ordinal variables / Other
Analysis	Statistical analysis	List of statistical analysis used in the method
	Other analysis	List of other type of analysis used in the method

The first set of variables deal with the article reference. The variables are classical in literature review such as authors, country, discipline, etc.

We identified the type of risk studied, including natural hazards, climate change–related risks, and other risks. Because natural hazards are a major threat to forests, we further distinguished the specific hazards considered (e.g., wind, wildfire, insect outbreaks). We also recorded whether studies examined interactions between multiple risks. To assess this, we qualitatively reviewed survey questionnaires and interview guides to determine whether respondents were asked to consider interactions, combined effects, or relationships between risks (“Risks interaction” in Table 1).

The analysis of methodologies used in the corpus was divided into three parts (Table 1). First, the methodological framework identified whether studies adopted quantitative approaches, based on the statistical analysis of numerical data, qualitative approaches, based on the interpretation of non-numerical data such as interviews or discourse, or mixed-methods approaches combining both. We also distinguished between theory-driven studies, which relied on conceptual frameworks such as Expected Utility Theory and empirically tested their assumptions or parameters using original data collected by the authors, and fully empirical studies, which analyzed observed data without relying on an explicit theoretical framework. Among these empirical studies, we further differentiated between econometric modelling approaches, which developed conceptual or formal analytical models to explain relationships between variables, and descriptive or inferential statistical approaches, which relied on statistical analyses without constructing an explicit conceptual model.

The variable “Research protocol” describes the type of actors considered in the study, the methods used to collect the data, and the nature and characteristics of the data that was collected.

Finally, we identified the type of analysis conducted.

### 3. Results

We present the results related to the risks studied and the methodology. The variable “Article reference” are presented in an additional bibliometric analysis available online.<sup>3</sup>

#### 3.1. Analysis of the risks studied

##### 3.1.1. Risks studied

Among the 158 articles reviewed, 105 focus on natural hazard perception, highlighting their central role as drivers of forest damage. Wildfire is by far the most studied hazard (78 articles), followed by insects (23), wind (2), and other hazards (24), including invasive plants, pathogens, drought, floods, frost, snow, wildlife, and erosion. Of the wildfire studies, 62 examine residents’ perceptions and 49 focus on the United States (Table 2). Insects account for around 15% of publications, reflecting their major impacts on forests (Patacca et al. 2023). By contrast, wind remains largely overlooked despite being the leading source of forest damage in Europe. Overall, the literature shows a strong geographical and thematic concentration, with North America dominating research while Europe remains comparatively underrepresented despite significant disturbances. Hazards particularly relevant in Europe, such as storms, receive little attention, and only a few studies focus on France, despite the importance of private forests and increasing natural hazards. Other continents are even less represented, leaving large regions understudied. These patterns largely mirror the geographical distribution and severity of hazards themselves, as the most frequent and damaging risks tend to attract the most scientific attention.

**Table 2.** Most frequent country-risk context pairs.

Country	Risk	No. of articles
USA	Wildfire	49
USA	Insects	8
Canada	Climate change	7
Sweden	Climate change	6
USA	Climate change	6

Climate change is addressed in 48 articles, reflecting its growing importance as a source of disturbance and uncertainty for forest decision-makers (Seidl et al. 2017). However, perceptions of climate-related risks depend strongly on how questions are framed. Studies focusing on specific hazards allow clearer interpretation of respondents’ judgments, whereas broad references to “climate change” often remain ambiguous. Respondents may associate climate change with very different hazards depending on local contexts, such as wildfires in California or drought and insect outbreaks in eastern France. Many studies based on the Climate Change Risk Perception Model (CCRPM; van der Linden 2015) rely on broad, non-specific questions, limiting their usefulness for understanding management decisions. Qualitative approaches can partly address this issue by revealing which hazards respondents implicitly associate with climate change. Some quantitative studies specify concrete impacts such as drought or insect infestations (Onyekuru and Marchant 2017), but these remain relatively rare.

Research on climate change mainly examines perceived impacts and social representations, reflecting political pressure for forest adaptation. The remaining 11 articles address other risks, including institutional processes, territorial policies, economic factors such as timber price fluctuations, and human behavior. These dimensions remain marginal in the literature, partly because forestry’s long temporal cycles make it less sensitive to rapid policy changes (Bastit et al. 2023). Moreover, economic and institutional risks are often treated as consequences or amplifiers of natural hazards rather than as distinct categories of risk.

<sup>3</sup>Barrey, Clémence; Brunette, Marielle, 2026, "Bibliometric analysis of the literature – Perception of multirisk in forests", <https://doi.org/10.57745/YKK9MJ>, Recherche Data Gouv, V1

### 3.1.2. Focus on multirisk

An advanced search across the full content of the 158 articles found no occurrence of multi(-)risk(s). Only a single study explicitly addressed an interacting linkage between hazards; all others treated risks as independent or separate questions. Specifically, Craig et al. (2020) included a question about the "perceived link between drought and fire risk", in which respondents rated their agreement on a Likert scale. This absence indicates either that the concept of multirisk, though recognized for describing interactions between natural hazards, is not used in the literature, or that no study specifically addresses its perception in forestry. To assess which case applies, an advanced search was carried out using terms belonging to the lexical field of multirisk: *compounding, compounded, multiple risk(s), interconnected, interconnection, interdependent, interdependence, interdependency(ies), cascading, domino, multi(-)hazard(s), interrelated, interrelation* and *multiple hazard(s)*. The word *interaction(s)* was excluded, as it is too general, whereas more specific vocabulary allows for greater targeting of relevant publications.

Of the 158 articles reviewed, 42 contain at least one selected keyword. Results reveal no occurrence of these terms in central discussions, confirming that the perception of multirisk in forests has not yet been directly studied. Among the 71 identified words, 46 are off-topic, appearing in contexts unrelated to multirisk. For instance, the term interdependency is used related to the expression "risk interdependency," found in studies on forest fires, which refers to protective measures put in place by one neighbor affecting the risk incurred by others. Other example is that the word multiple in multiple risks is used as a synonym for several, without reference to the concept of multirisk as understood here.

Fifteen words appear in secondary contexts, which means they are mentioned as part of results but are not analyzed in depth. For instance, in Soucy et al. (2021), the terms compounding and cascading are reported in interviews, describing how insects and pathogens interact with other hazards like fire or drought, yet the study does not further examine this point. Similarly, in Flint and Haynes (2006), cascading risk appears in interviews but not discussed analytically. Secondary contexts include also terms cited as existing concepts or future research directions. For example, Collins (2009) briefly mention multihazard in the discussion to note a general shift in risk studies toward multirisk approaches. Likewise, Newman et al. (2014) refer to the lack of research on risk perception in multi-hazard contexts and the need to develop research in this area, without addressing it in their own analysis. Finally, the analysis shows that multirisk vocabulary is rarely used in the literature. When it does appear, its use remains marginal and adds little depth. This finding is nevertheless unsurprising, as the concept of multirisk remains relatively recent in forest and environmental risk research, where hazards have traditionally been studied separately rather than through their interactions and cascading effects. Semantically, much work remains to be done, as this field is still largely unexplored. Overall, the perception of multirisk in forestry emerges as an underexplored topic warranting further research.

## 3.2. Analysis of the methodologies used

### 3.2.1. Analysis of methodological framework

In this section, we summarize the qualitative/quantitative nature of the methods, and delve deeper into the methodological approaches taken in the corpus (Table 1). In terms of the nature of the methods, 104 analyses are quantitative, 19 are qualitative, and 35 are mixed (Table 3). Studies using a mixed method generally have one dominant approach. An example of a predominantly quantitative study with some qualitative elements would be interviews to construct a final questionnaire, with open-ended questions whose responses are then categorized, or a questionnaire with closed questions supplemented by an open-ended question to capture additional information.

**Table 3.** Number of paper of the corpus according to the type of methodological framework.

Variables	Categories	No. of articles
Nature of the method	Quantitative	104
	Qualitative	19
	Mixed	35
Methodological approach	Theory-driven study	3
	Empirical	155
Econometric model	Yes	76
	No	82

Only 3 studies are theory-driven, while the other 155 are based on an empirical method (Table 3). These empirical studies either applied econometric models to formally analyse relationships between variables, used descriptive and inferential statistical analyses without explicit modelling, or relied on non-statistical qualitative approaches.

The model proposed by Dai et al. (2023) combines expected utility theory (risk aversion theory), the insurance model of Pratt (1964), and portfolio theory introduced by Markowitz (1952). The utility function measures the amount an agricultural household is willing to pay to avoid risk, defined as the risk premium, i.e. the difference between expected returns and the certainty equivalent of the lottery. This willingness to pay is captured by the expected utility of a risky investment. The risk premium reflects the degree of risk aversion, measured through the absolute risk aversion coefficient proposed by Pratt (1964). Households therefore make forest investment decisions according to their perception of risk, represented by the variance in expected returns, and their level of risk aversion. This framework links risk perception to behavior. Dai et al. (2023) then use the model to explain how public policies modify risk perception, influence investment allocation, and affect forestry income.

In their study, Wale et al. (2022) rely on Random Utility Maximization (RUM) theory (McFadden 1974; Thurstone 1927) to understand how farming households choose climate change adaptation strategies. Individual preferences are heterogeneous and may arise from personal tastes, socio-demographic characteristics, or beliefs. While classical theory assumes a deterministic utility function, observed choices actually reflect multiple utilities. Thurstone (1927) therefore interpreted variability in individual choices as stemming from this heterogeneity.

McFadden (1974) introduced a random term into deterministic utility to represent the gap between average tastes and the utility perceived by each individual. This term captures both the distribution of preferences and the non-repetitive nature of decisions, especially under climate uncertainty. In Wale et al. (2022), households assign a utility to each adaptation strategy and select the one maximizing perceived utility. Each strategy combines observable factors (income, access to resources, socioeconomic characteristics) and an unobservable stochastic component related to preferences. A multinomial logit model links strategy choice to socioeconomic and institutional factors. RUM thus provides a microeconomic interpretation of adaptation decisions. Gan et al. (2014) also use random utility theory through a logistic regression model identifying the factors influencing landowners' wildfire insurance decisions. Utility depends on fire characteristics, owner attributes, insurance contract features, and beliefs. These two studies appear to be the only ones applying this widely used framework.

Of the remaining 155 articles, 76 use econometric models (Table 3). These studies developed analytical frameworks to explain relationships between variables and identify determinants of risk perception or behavior, whereas other studies relied only on descriptive or inferential statistics. Most econometric models are grounded in conceptual frameworks from psychological sciences, where researchers developed theoretical schemes linking cognitive, experiential, and social variables involved in risk perception. These conceptualizations are adapted into empirical models for econometric analysis.

For instance, Protection Motivation Theory (PMT), cited in four articles including Villamor et al. (2024), explains protective behaviors in response to threats through assessments of risk severity, probability, and coping ability. The Climate Change Risk Perception Model, identified in seven papers including Lacroix et al. (2020)

and developed by van der Linden (2015), integrates cognitive, experiential, socio-cultural, and demographic factors to explain how climate risk perception shapes support for climate policies.

Overall, these frameworks mainly serve as empirical bases for econometric analysis. Their repeated use strengthens their credibility. Most other studies relying on conceptual frameworks use either composite frameworks combining existing psychological and social models or frameworks specifically developed for the study.

### **3.2.2. Empirical research design**

Of the 158 articles reviewed, 155 used surveys, either partially or exclusively. Most surveys relied on closed questionnaires (Table 4), sometimes complemented by interviews or focus groups to capture information difficult to obtain through multiple-choice questions. Surveys were mainly conducted in person (68 papers) or by mail (59). Sample sizes were relatively balanced, although most empirical studies relied on 100–500 respondents (62 studies). Forest risk perception was primarily examined at local and regional scales (128 studies).

A wide range of stakeholders was surveyed (Table 4). Local residents were the most studied group (94 articles), followed by forest decision-makers (professionals, 50 articles; private forest owners, 43 articles). NGOs, visitors, and the general public received less attention. Variables included socio-economic and demographic characteristics, widely recognized as influential, as well as socio-cultural dimensions such as experience and knowledge. Other variables concerned management or mitigation actions and the spatial or temporal context. Although highly diverse, these variables can be grouped into broad categories. Table 5 illustrates this classification through selected examples. It highlights the strong presence of socio-demographic variables, risk perception indicators, cognitive and cultural factors, and management-related behaviors. A more precise classification would have been useful, but the variety of terms describing similar dimensions complicates such an approach.

Most measurements of risk perception are based on Likert scales (104 papers), producing ordinal variables used to assess concern, agreement, satisfaction, or related dimensions. Dichotomous yes/no questions were also common (54 papers), resulting in binary variables. Surveys may additionally combine responses into composite indicators of risk perception. For example, Flint (2007) constructed a composite satisfaction score from stakeholder ratings of forest resource managers involved in bark beetle management. Open-ended questions were sometimes categorized into variables. These standardized measurement methods were used only in quantitative studies, whereas qualitative interview-based analyses relied on non-standardized approaches.

**Table 4.** Number of paper of the scope according to the type of research protocol.

<b>Variables</b>	<b>Categories</b>	<b>No. of articles</b>
Type of actor	Public forestry professionals	39
	Private forestry professionals	11
	Private forest owners	43
	Scientists	12
	Local residents	94
	NGOs	4
	Visitors	3
	General public	5
	Other type of actor	8
Data collection	Structured interview	28
	Semi-structured interview	21
	In-depth interview	14
	Focus group	15
	Closed-ended questionnaire	123
	Open-ended questionnaire	26
	Experimental economics	0
	Others	1
Mode of administration	In person	68
	Mail	59
	Phone	10
	Online	33
	Paper based	25
Sample size	≤ 20	6
	(20;50]	11
	(50;100]	15
	(100;200]	21
	(200;500]	41
	(500;1000]	30
	(1000;2000]	23
	≥ 2000	9
	Unspecified	2
Scale	Local	56
	Regional	72
	National	22
	Transnational	9
Investigation method	Cross-sectional	146
	Longitudinal	12
Data type	Likert scale	104
	Binary variables	54
	Categorical variables	52
	Other	25
	Multiple choice	10
	Continuous variables	6
	Other scale	4
	Ordinal variables	3

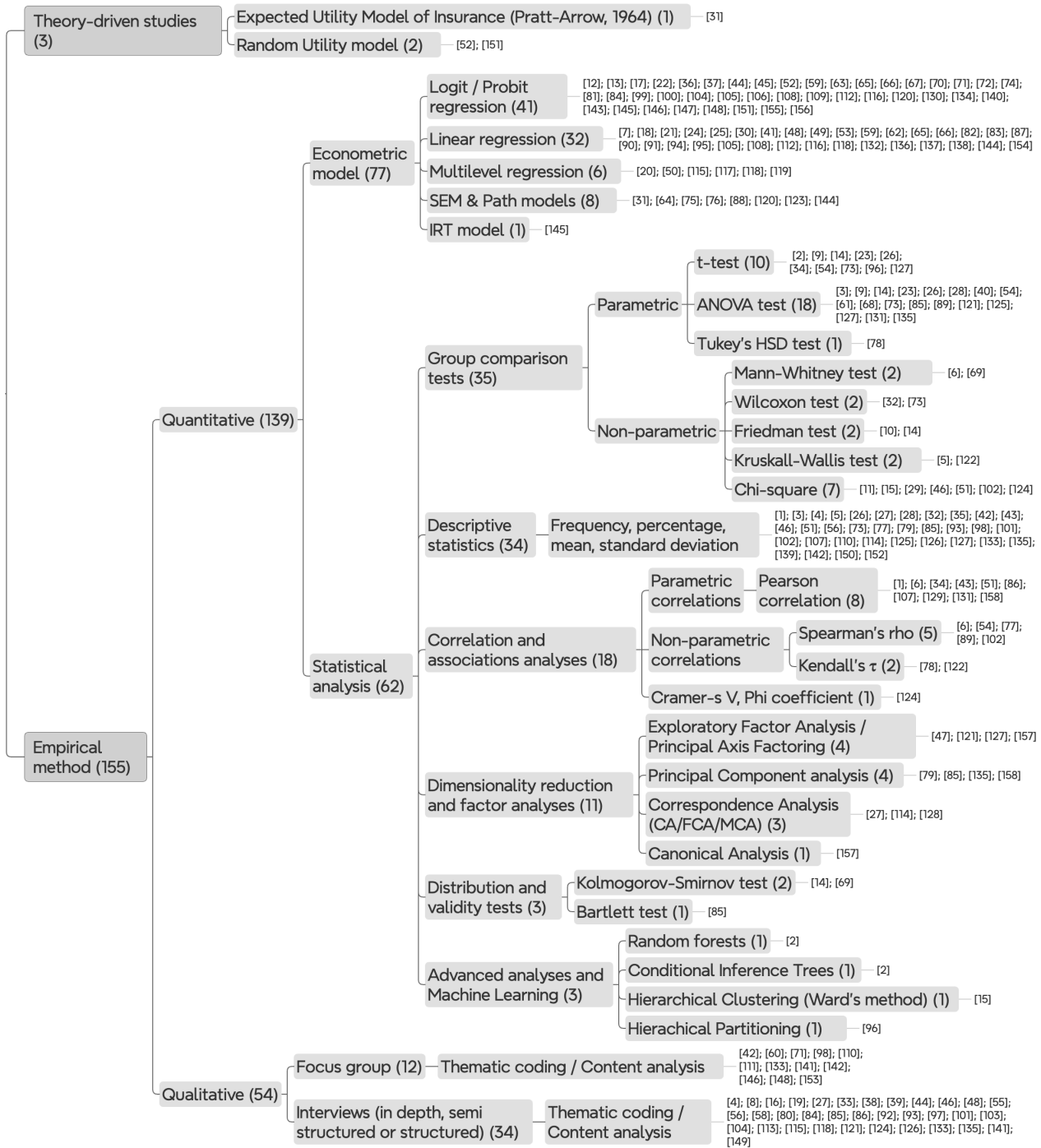
**Table 5.** Examples of variables used in the literature on forest risk perception, classified by category.

Categories	Examples of subjective probabilities	Examples of objective probabilities
<b>Risk</b>	Perception of risk: <i>Climate change risk perception</i> (Lacroix et al. 2020); <i>Concern about forest risk</i> (Qin and Flint 2010)	Primary data
<b>Hazard</b>	Perception of hazards: <i>Perceived disturbance intensity</i> (Qin 2015)	Hazard characteristics: Primary data: <i>Temperature and rainfall</i> (Onyekuru and Marchant 2017)
<b>Vulnerability / Exposure / Impacts</b>	Vulnerability, exposure, perceived impacts: <i>Perceived hazards causing the greatest financial loss</i> (Blennow and Sallnäs 2002); <i>Perceived damage</i> ; <i>Perceived security</i> (Dai et al. 2023); <i>Perceived tree mortality</i> (Qin et al. 2023)	Vulnerability : Forest physical characteristics: <i>Size of forest</i> (Eriksson 2014); <i>Type of forest</i> (Onyekuru and Marchant 2017)
<b>Response</b>	Perception of response: Judgment of management options / perception of the best management choices: <i>Perception of the effectiveness of conservation strategies</i> (McFarlane 2005); <i>Satisfaction with forest resource managers</i> (Flint 2007); <i>Faith in forest industry</i> (Flint and Luloff 2007)	Concrete management practices: <i>Actions taken to reduce risk</i> (Blennow and Sallnäs 2002); <i>Forest vegetation management alternatives</i> (Wagner et al. 1998)
<b>Individual</b>	Socio-economic and demographic characteristics: <i>Age, Income, Gender, Education</i> (present in most studies); <i>Timber-dependence</i> (Wagner et al. 1998) Cultural and cognitive characteristics: <i>Personal experience with emergencies; Number of information sources; Community participation</i> (Qin et al. 2023); <i>Climate change knowledge; Values</i> (Lacroix et al. 2020) Note: a very large number of variables appear in this category	
<b>Management behavior</b>	<i>Mitigation / management behavior</i> (Fischer and Charnley 2012)	
<b>Socio-economic and spatio-temporal context</b>		<i>Protected area policy</i> (Dai et al. 2023)

### 3.2.3. Analytical methods used in the literature

Figure 3 presents a non-exhaustive overview of the analyses identified in the studies. To simplify reading, only the highest level of analysis was retained for each study. For econometric studies, only the regression model was considered, without detailing additional statistical analyses. This distinction highlights the four economic models presented above, as well as the empirical methods organized into quantitative and qualitative approaches.

On the quantitative side, econometric models are mainly operationalized through regressions, particularly logit/probit models (41) and linear regressions (32). For example, Flint and Luloff (2007) explained community activeness in response to forest risk using variables such as perceptions of tree mortality, forest regeneration, satisfaction with public managers, trust in the forestry industry, emergency experience, risk perception, and community communication. Among the 77 studies using econometric models, 25 focused on sociocultural and cognitive determinants of risk perception, while 52 examined management behaviors, adaptation intentions, community participation, management strategies, and implemented actions as functions of perceived risks and sociocultural factors.



**Figure 3.** Overview of methodologies used in the reviewed scientific articles. References listed in brackets [] are available in Appendix A.

Other statistical analyses also appear frequently, including descriptive statistics, group comparison tests, and validity or distribution tests assessing data robustness. Correlation and association analyses are commonly used to examine relationships between risk perception, sociocultural and demographic factors, and management actions. Some studies additionally apply factorial or dimensional analyses and more advanced methods to model complex relationships. Qualitative approaches rely mainly on thematic coding and content analysis, allowing researchers to identify and interpret recurring themes in interviews and better understand participants' perceptions, beliefs, and representations.

## 4. Discussion

### 4.1. Lack of multirisk perception studies

In this literature review, we sought to determine whether existing approaches to forest risk perception are relevant for addressing the challenge of multiple risks. The results show that, with the exception of one, almost no scientific paper explicitly focuses on the perception of multiple *interacting* risks in forests. Assuming that this review has adequately covered the existing literature on forest risk perception, this conclusion can be extended to the body of studies currently available. Indeed, most studies focus on single risks considered in isolation.

Climate change is a slow and diffuse process that is not easily grasped through personal experience or disaster preparedness (Lacroix et al. 2020). As a result, closed questions such as "How much impact does climate change have on your forests?" (Dey et al. 2017) make it unclear which events respondents associate with the term, such as drought, wildfire, insect outbreaks, or media representations, introducing potential biases. For instance, Dey et al. (2017) found that some respondents in India perceived climate change as causing forest decline, despite official records showing increasing forest cover, illustrating how perceived environmental change may diverge from observed ecological trends.

The development of research on multirisk in forests is hindered by the absence of a shared and operational conceptualization of the term. Although the notion emerged in Agenda 21 and was later adopted by several research fields, including the IPCC (2023b) under the concept of "risk complexity," no common framework has yet emerged. As a result, multirisk remains loosely defined in both academic and practical contexts (Brunette et al. 2025; Curt 2021; Simpson et al. 2021). This lack of conceptual clarity complicates the structuring and comparability of research. Existing typologies also remain fragmented. For example, Simpson et al. (2021) distinguishes between single risks, interactions between determinants of the same risk, and interactions between multiple risks. The IPCC proposes categories such as aggregate, compound, and cascading risks, the latter being illustrated by drought episodes weakening conifer plantations and increasing vulnerability to bark beetle outbreaks in central Europe (Brunette et al. 2025).

However, this conclusion deserves nuance. Many of the 158 studies reviewed investigate several forest risks within the same survey, even if they ultimately treat them as separate variables. It therefore remains unclear whether respondents themselves perceive these risks independently when answering. Individuals concerned about multiple risks may already integrate possible interactions or cumulative effects into their perceptions. Qualitative approaches focusing on discourse and narratives could help better capture these underlying representations. Further research is therefore needed to determine whether perceptions of interacting risks are already implicitly present in existing studies.

### 4.2. Empirical dominance and theoretical gaps in forest risk perception research

Most studies rely on empirical econometric analyses aimed at identifying determinants of risk perception or adaptation behavior, often through regression-based approaches such as logit or probit models. However, only a limited number explicitly anchor their analyses within formal behavioral or economic frameworks, such as Expected Utility Theory or Random Utility Maximization. As a result, many studies remain exploratory and focus on correlations between socioeconomic variables and perceived risks rather than testing theoretically grounded behavioral mechanisms.

This result may also reflect the distinction between studies focusing on forest risk perception and those addressing forest management under uncertainty. While the former rarely rely on explicit theoretical frameworks, the latter frequently mobilize formal economic theories such as Expected Utility Theory, portfolio theory, or risk aversion models, particularly in studies on optimal rotation, thinning, or species diversification. These approaches are well developed in forest economics but generally analyze decision-making under risk rather than risk perception itself. Perception is inherently subjective, and most studies assess it through self-reported survey responses. However, stated perceptions do not necessarily correspond to objective risks, as individuals

may misperceive both probabilities and magnitudes of events.

Experimental and behavioral economics offer established frameworks for analyzing risk perception, yet only three studies in the review adopt an explicit theoretical approach. Among these, Prospect Theory (PT), developed by Tversky and Kahneman (1971), appears particularly relevant. PT has proven effective in explaining cognitive biases and deviations from expected utility theory in environmental risk contexts (Bartczak et al. 2015; Riddel 2012; Villacis et al. 2021). Unlike expected utility theory, PT incorporates reference dependence, loss aversion, and subjective probability weighting. These dimensions are especially relevant for climate-related risks, where rare but salient events such as droughts or wildfires can disproportionately shape perceptions and decision-making (Villacis et al. 2021).

Most PT-based studies combine theoretical modeling with experimental elicitation of risk preferences and econometric estimation, allowing researchers to observe rather than assume behavioral preferences. For example, Villacis et al. (2021) show that loss aversion significantly shapes climate risk perception. Despite this evidence, behavioral dimensions such as probability weighting or loss aversion remain largely absent from the forest risk perception literature reviewed here (Sitkin and Pablo 1992). Some recent PT-based forest studies were also not captured in the review due to keyword selection. Notably, Alpenberg et al. (2025) applies PT to forest investment decisions under environmental uncertainty.

Finally, experimental economics methods remain largely absent from the literature, despite their potential to identify causal relationships, rigorously test economic theories, reduce declarative biases, and observe responses to economic incentives (Table 4).

### **4.3. Patterns and gaps in empirical designs of forest risk perception research**

This literature review included all stakeholders to cover the widest possible spectrum of existing work. However, the main focus is on foresters, i.e., owners and managers responsible for forest plots, as they directly implement management measures. The results in Section 3.2.2 show that only 61 scientific articles deal, at least partially, with the perceptions of forestry decision-makers, which remains limited. Conversely, many studies focus on local residents, mainly due to US policies encouraging citizens to protect homes from forest fires.

The predominance of local-scale studies is consistent with the strong focus on wildfire risk perception among residents. While understandable, this reveals a gap regarding forest risk perception at broader spatial scales. Such approaches would be particularly relevant for capturing global forest risk dynamics linked to climate change and changing disturbance regimes. Most studies are cross-sectional, whereas longitudinal approaches generally examine changes in risk perception before and after hazards, especially forest fires, to analyze the influence of experience on mitigation behaviors.

The variables analyzed cover the main dimensions of risk perception identified in the literature. Risk assessment combines objective and subjective probabilities, characteristics of hazards, individual and socio-cultural factors, and cognitive biases, in line with the psychometric paradigm. These dimensions largely relate to the four main determinants of risk: hazard, vulnerability, exposure, and response.

### **4.4. Implications of the existing literature for future research**

We show that no paper addresses the perception of multirisk, which justifies exploring it directly. In the absence of existing work, it becomes relevant to ask what a study on multiple risk perception might look like. Nevertheless, the literature identifies several relevant methods for understanding forest risk perception. Although currently applied to individual risks, these methods could be extended to multiple risks. In particular, survey methods appear promising for measuring individuals' perceptions of multirisk.

The literature review gathered essential information on multirisk, risk perception, and the role of forest managers in the multirisk approach. Through management practices, forest managers influence forest vulnerability, damage intensity, and ultimately risk levels. In a multirisk perspective, this involves identifying hazards, examining causal relationships, probabilities of occurrence, and temporal links. Regarding multirisk perception, Kouabénan et al. (2007) distinguish three major paradigms: the expected utility paradigm, based on objective

and subjective probabilities; the psychometric paradigm, emphasizing social, cultural, and individual characteristics; and the cognitive paradigm, highlighting cognitive and heuristic biases. In the context of multirisk, the cumulative probability bias described by Tversky and Kahneman (1971) illustrates how short-term rational decisions may ultimately conflict with long-term objectives.

#### **4.5. Implications for policies on forest risk management**

The contributions of behavioral economics provide valuable insights for designing public policies and economic models in forestry. By highlighting the role of subjective risk perceptions, individual preferences, and cognitive biases in management behaviors, this literature reveals the limits of traditional approaches assuming fully rational agents. Developing evaluation frameworks that incorporate socially shaped preferences and support policy comparison therefore remains a major challenge.

Risk perception analysis also sheds light on the notion of “acceptable risk,” which varies across disciplines. While conventional economic approaches rely on market mechanisms to arbitrate between risks and benefits, environmental and forest risks involve collective dimensions that often justify public intervention. Yet regulatory frameworks rarely account for individuals’ cognitive limitations and subjective perceptions. In contrast, approaches rooted in economic psychology, based on the elicitation of preferences and perceptions, encourage democratic participation and improve understanding of attitudes toward risk, despite the instability of expressed preferences (Kunreuther and Slovic 1978).

Moreover, several studies, including Villacis et al. (2021), suggest that changing risk-related behaviors is often more effective when policies target risk perceptions rather than relying only on economic incentives. In a context of climate change and increasing forest risks, identifying the determinants of risk perception is therefore crucial for public action. Policies improving information, education, and awareness may encourage adaptation and risk management strategies if they are designed consistently with the behavioral mechanisms identified in the literature.

### **5. Conclusion**

The results of this systematic review on forest risk perception contribute to research on how forestry decision-makers consider risks. Studying multirisk perception lies at the intersection of psychology and economics, combining formal approaches to better understand forest owners’ behavior and inform sustainable management strategies. This review highlights key findings. Most studies rely on survey-based approaches using questionnaires and Likert scales administered to stakeholders, followed by econometric analyses to identify determinants of risk perception or its effects on forest management practices. However, the literature shows weak theoretical grounding despite behavioral decision-making frameworks accounting for the cognitive and social dimensions of risk. Most studies remain empirical and lack explicit economic theory, limiting interpretation and generalizability.

A major finding is that no scientific article examines the perception of multiple risks through their interactions and combined effects on forests. This absence is paradoxical given that climate change is modifying disturbance regimes and increasing interacting risks. Integrating this dimension into future research therefore appears essential. This review has several limitations. The analysis is restricted to peer-reviewed English-language articles indexed in selected databases, potentially excluding grey literature and studies from other contexts. In addition, categorizing variables, methodologies, and theoretical approaches involved interpretation. Finally, the heterogeneity of concepts and measurement methods complicated comparisons and limited a standardized synthesis.

Overall, this review highlights underexplored research areas regarding multiple risks in forests. These gaps call for further investigation through stronger attention to multirisk perception and greater use of decision-theoretic frameworks. Combining empirical and theoretical approaches would strengthen future findings.

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## Appendix A. List of the 158 research papers.

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