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FIRE-RES

Innovative technologies & socio-ecological-economic solutions for fire resilient territories in Europe

D3.5 IA 3.3a brief: Technical report on methodology and procedures to design and setup parametric-insurance products for wildfires

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D3.5 IA 3.3A BRIEF: TECHNICAL REPORT ON METHODOLOGY AND PROCEDURES TO DESIGN AND SETUP PARAMETRIC-INSURANCE PRODUCTS FOR WILDFIRES

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Abstract: This report explores risk transfer solutions from a user-centric perspective, aiming to highlight the requirements for the design of parametric wildfire insurance products by aggregating insights and identifying opportunities from diverse industry stakeholders. Beginning with an introduction to the context of wildfire activity and losses in Europe, the report summarizes the receptiveness of insurance players towards innovative insurance solutions. Building upon this foundation, the report delineates the skeletal structure and methodological requisites to serve as a blueprint for the development of a resilient framework accommodating the varied needs and aspirations of stakeholders in the insurance and brokerage sectors.

Keywords: parametric risk transfer, wildfire insurance, alternative risk transfer, climate change

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0.Acronyms

EU: European Union

EC: European Commission

ERA: ECMWF Re-Analysis

JRC: Joint Research Center

EFFIS: European Forest Fire Information System

EIOPA: European Insurance and Occupational Pension Authority

ECB: European Central Bank

GDP: Gross domestic product

CCR: Caisse Central de Reassurance

CCS: Consorcio de Compensación de Seguros

INRAE: France's National Research Institute for Agriculture

IEFC: European Institute of Planted Forest

CTFC: Catalan Forest Science and Technology Centre

NASA: National Aeronautics and Space Administration

FWI: Canadian Fire Weather Index

IDD: Insurance Distribution Directive

CJEU: Court of Justice of the European Union

1. Introduction

The European wildfire market is currently undergoing significant scrutiny and evolution due to the rising frequency and intensity of wildfires, which are exacerbated by climate change, changes in land use, and multiple and complex socio-economic factors. This report offers a comprehensive overview of how the European insurance industry is providing financial relief and how alternative risk transfer transactions are offering additional, more affordable, and faster payment options.

The financial strain on many regions is increasing. According to a 2023 study conducted by the Joint Research Centre of the European Union, 2022 marked the second-worst year for wildfires, with an area roughly equivalent to the size of Corsica scorched by wildfires in the EU. The latest JRC (Join Research Center) report about wildfires in the pan-European region underscores this severity (*Wildfires in the EU: 2022 Was the Second-Worst Year, a Warning from a Changing Climate*, n.d.)

In this report, we provide an overview of the risk of wildfire in Europe and deep dive into the countries with the current highest wildfire risk combined with a huge protection gap, namely the Mediterranean countries Spain, Portugal, Greece, Italy and France. We also show an overview of different methodologies aimed at understanding user and industry needs from the insurance sector. From there, we provide an outline of the technical requirements to develop a risk model for wildfires that can support parametric risk transfer for wildfires as a proof of concept in regions in Spain and Portugal.

2. The European context: more fires, limited coverage

Europe is increasingly susceptible to wildfires.

Data from the European Forest Fire Information System (EFFIS) shows the cumulative burnt areas over 22 years, starting from 2000 (Figure 1).

The Mediterranean is particularly affected, with high levels of cumulative burnt areas in the centre and north of Portugal, centre of Spain, Sardinia, Corsica, southern Italy, Sicilia, Montenegro, Greece, Turkey, Cyprus, and Croatia. These locations were also home to multiple large wildfires during this period.

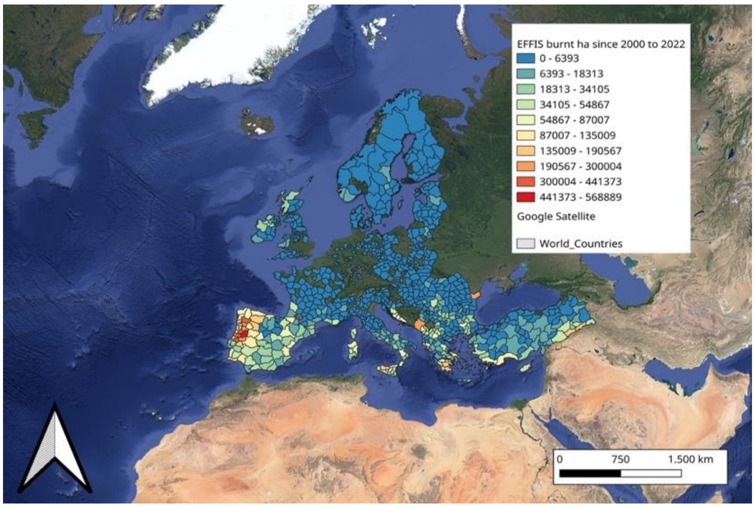

Figure 1 - Aggregation of EFFIS burnt area from 2000 to 2022

Fire seasons do not follow linear trends. Yet the correlation coefficient can be computed to see if it appears a linear correlation and if it is increasing or decreasing (Figure 2).

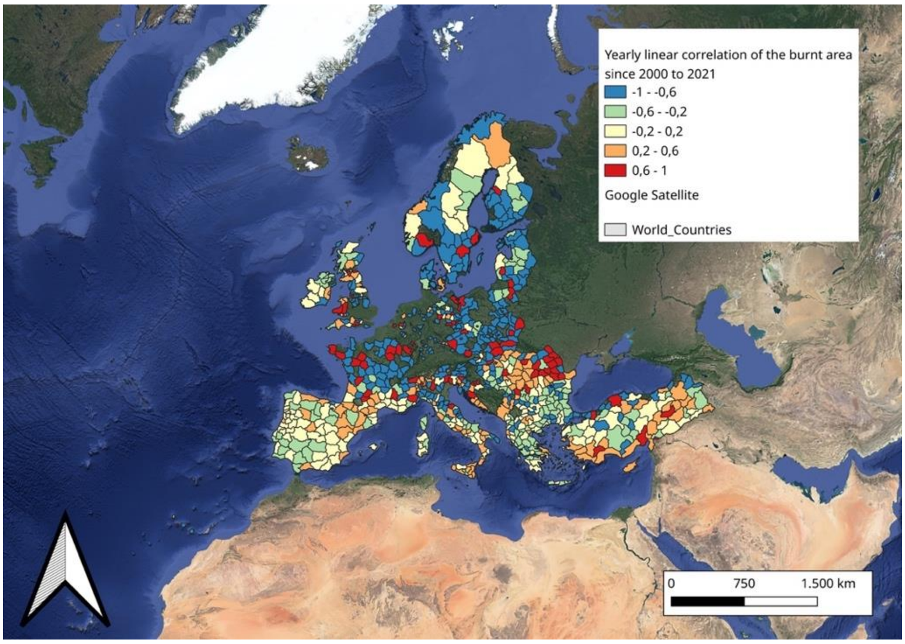

Figure 2 Linear correlation coefficient between burnt areas and years (annual aggregation)

Some locations got worse with time in terms of burnt area (Sicily, Mediterranean coast of Turkey, some regions of Greece, Italy, and northern areas of Spain). In the north of Europe, large fires are increasing in Sweden whereas in Estonia, there are more small fires that translates into a moderate or stable trend of total burnt area.

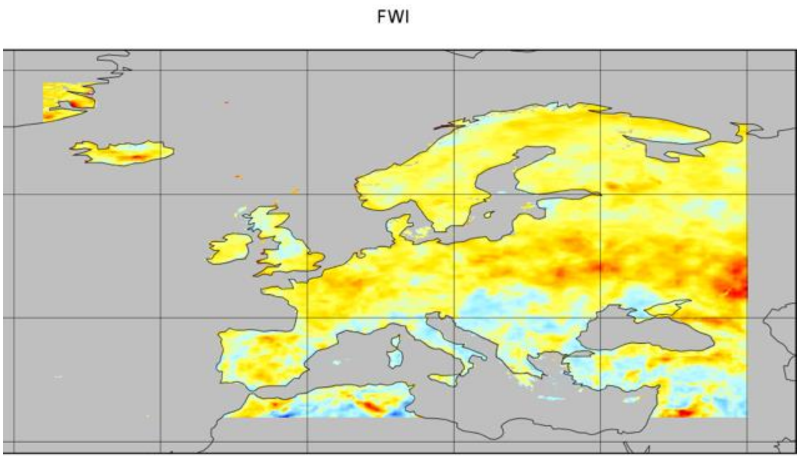

Figure 3. Trend (Linear correlation factor) of the Fire Weather Index computed in Mitiga from ERA5 Land from 2000 to 2021.

Given the complex nature of wildfires, to add another layer of dimension to the situation of wildfires in Europe, Mitiga computed the Canadian Fire Weather Index (Wagner & Service, 1987) using ERA5 Land at 9 km from 2000 to 2021 for Europe, and a linear correlation factor. Figure 3 shows how **the total burnt area is indeed worsening in some northern areas of Europe and the weather conditions are getting more severe overall.**

Against this backdrop, Europeans now face yet a concerning reality: they are among the **least insured against certain types of extreme weather and natural disasters in the developed world.**

The summer of 2023 bore witness to a succession of devastating heatwaves, wildfires, and droughts, underscoring the urgent need for robust risk mitigation strategies (*Bloomberg*, n.d.). Research conducted by the European Central Bank and EIOPA (European Insurance and Occupational Pension Authority) confirms this trend: merely a quarter of climate-related catastrophe losses are currently insured in the EU, with some countries registering insurance coverage rates below 5%. Amidst these challenges, the European insurance market confronts obstacles in providing adequate coverage as part of standard insurance policies. A 2023 publication by Munich Re (Lennert, 2023) showed that **approximately 90% of wildfire losses in the first**

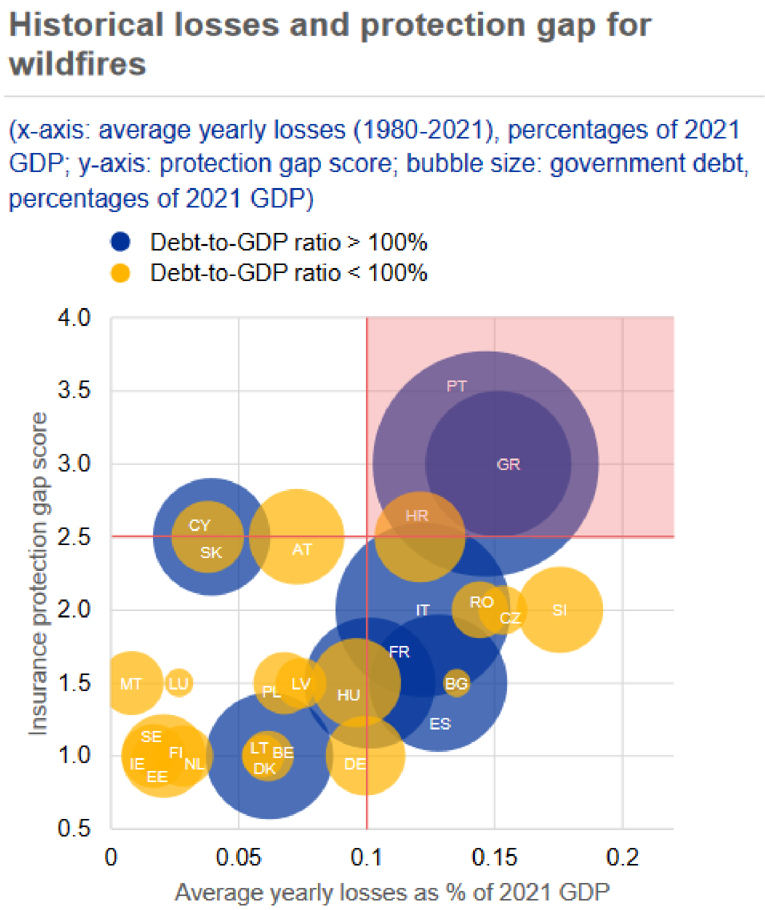

Figure 4. Historical losses and protection gap for Wildfires (Authority, 2023).

half of 2023 remained uninsured. Furthermore, research from the European Central Bank indicates that **coverage for losses stemming from natural catastrophes is becoming prohibitively expensive**, exacerbating the protection gap (European Central Bank, 2023).

The macroeconomic repercussions of extreme weather events are increasingly recognized, particularly in the Mediterranean region (with relatively high losses compared to GDP), underscoring the vital role of catastrophe insurance in providing swift funding for reconstruction efforts and incentivizing proactive risk reduction measures.

3. Options of Insurance Coverage

Insurance provides opportunities to enhance the coverage of wildfire damage.

Innovative schema also includes coverage for wildfire risks through innovative risk transfer mechanisms, public-private partnerships, and regulatory reforms (Hazra & Gallagher, 2022). The EIOPA and the EU have conducted a detailed report on the status of insurance for physical climate change risk, highlighting that for most of the perils, wildfire has one of the lowest insurance coverage rates, seeing only 5% being ceded to reinsurers (EIOPA and ECB Call for Increased Uptake of Climate Catastrophe Insurance, n.d.; Staff Paper on Policy Options to Reduce the Climate Insurance Protection Gap, n.d.)

The main goal of an insurance is to cover a risk. The risk is related to a potential probability of occurrence, vulnerability, damage, and if the event really takes place, there is a real loss. However, not all the insurance solutions are directly related to a loss quantification. Mostly because the loss quantification may not be feasible or is too slow under some circumstances. For instance, in indemnity insurance, the compensation covers a loss. In this case, the loss must be quantified. On the other side, non-indemnity insurance may not be related and may not imply an accurate assessment of the loss. In addition, inside the non-indemnity group there are different modalities. The valued policy insurance is an agreement where the amount of the pay-off is not related with the real loss but triggered by an event or loss proxy threshold. Finally, the parametric insurance, which is based on a triggering event, the trigger is based on metrics. Then when a given threshold is reached, then it starts the pay-out mechanism which is a quick pre-agreed payout. Please see Figure 5 which shows the classification of insurance options commented in this section.

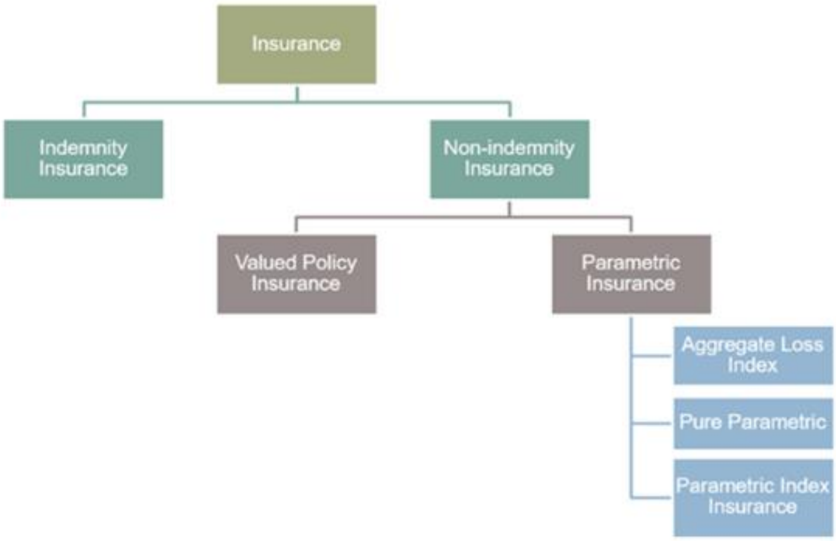

Figure 5. Classification of non-life insurance contracts. Source: (Lin & Kwon, 2019)

Emerging insurance products and solutions are available to address the unique challenges posed by wildfires, including as an example:

- **Parametric insurance**: It covers the probability of a predefined event happening based on an index. It does not consider the real loss for the amount to pay. There are three types of parametric insurance, namely:
    - *Aggregate loss index insurance*: the claim payment is based on an aggregate loss of an area. It is easy to develop and to scale up, however also more prone to tampering and less reliable due to the loss of data aggregation.
    - *Pure parametric:* the insurer provides a fixed payment when an event strikes a defined trigger. Once the data used for the trigger is accepted and the trigger is defined, it is a fast way to provide economic support to the insured, but it is not related to the amount of loss. It focuses on the quick payoff and simplicity of the elements to define the trigger.
    - *Parametric index insurance* models the potential loss (not just the trigger), so the pricing and payment structure is based on a model instead of a single trigger. For instance, Gu et al., 2023 introduces the analysis of economic losses and remarks on the importance of good methods for loss prediction. This insurance solution implies the usage of models or indexing for the payoff method.
- **Catastrophe (cat) bonds***:* It uses investment as a mechanism for insurance solutions. An insurance company issues bonds under a specific condition related to a trigger which measures a parameter of the event happening. When the event triggers the bond part of the investment is used to pay the sponsor. Most bonds attract funding from capital markets by being tradable instruments. Cat bonds are normally used to insure sure risks that insurance and reinsurance companies may not want to cover.
- **Risk pooling arrangements**: the main concept of pooling is to share losses and risks between the different participants of the pool. Then the risk is diversified between the members of the arrangement. Also, depending on the kind of arrangement it would prevent the insurer from collapsing when a massive number of events take place simultaneously causing major losses.

The benefits of the parametric solutions include the following:

- **Prompt claim payouts**: Insurance aims to provide timely claim pay-outs following natural disasters like wildfires, facilitating swift recovery and reconstruction efforts.
- **Incentivizing risk mitigation**: To avoid losses, insurance solutions incentivize the implementation of risk mitigation and adaptation measures, encouraging

proactive measures to reduce wildfire risks. In California, this is now part of a regulation (e.g., the California Code of Regulations Section 2644.9, approved in October 2022). The Code aims to decrease insurance expenses for policyholders who implement measures to safeguard their properties against wildfire threats (Understanding the New California Wildfire Rating Requirements, 2023).

- **Flexibility and simplicity**: There is full flexibility under the local insurance regulation. Insureds can be a group of individuals or large clients. Besides, there is no repair or replacement obligation, but just a payment that can be used for recovery or any other purpose.
- **Conflict reduction**: since the methodology is previously defined and based on third-party data providers, insurer and insured must accept all the terms in the contract.
- **Low transaction and operating costs**: it does not require an individualized assessment of risk and loss for each insured.

Parametric insurance methods are prone to basis risk biases ('difference between expectation and outcome'), positive or negative, then sometimes the payment could be below the loss and sometimes the loss can be none and anyway, the payment is done. See Figure 6.

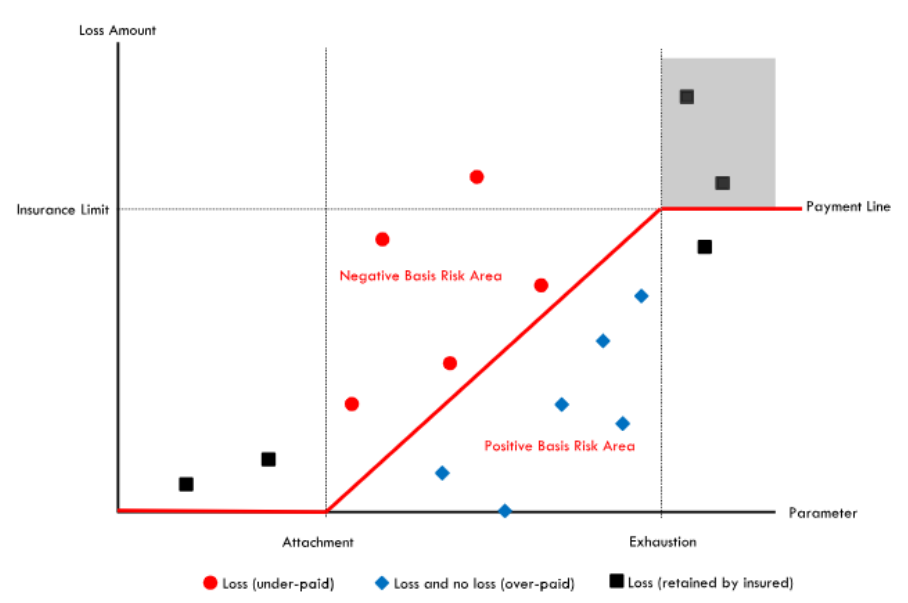

Figure 6. Illustration of the concept of positive/negative basis risk. Source: Lin Kwon (2019)

There are requirements for the implementation of these insurance schemes, including:

- **Data availability and quality**: Parametric insurance relies heavily on accurate and reliable data for trigger events and loss assessments. Moreover, this data should be trusted and preferably accessible by all parties involved. However, obtaining comprehensive and up-to-date data on wildfire risk exposure, historical wildfire patterns, and environmental factors in Europe can be challenging due to inconsistencies in data collection methods, incomplete historical records, and varying data standards across regions.

- **Trigger design and basis risk:** Parametric insurance contracts require clear and objective trigger mechanisms to determine pay-out eligibility. For wildfire risks, defining reliable triggers based on parameters such as wind speed, temperature, humidity, or satellite imagery poses challenges due to the inherent uncertainty and variability of wildfire behavior. Additionally, there may be instances of basis risk, where the occurrence of a trigger event does not necessarily correspond to the actual loss experienced by the insured party, leading to potential disputes and dissatisfaction.

- **Spatial and temporal aggregation**: The key to parametric insurance structures is to adequately address spatial and temporal aggregation of wildfire risks, so to match the risk pooling requirements of the cedant's exposure and the spatial-temporal dynamics of the hazard to minimize basis risk. Large-scale wildfire events can impact multiple insured parties simultaneously, leading to systemic risk exposures and potential liquidity issues for insurance providers. Moreover, parametric contracts may not capture the localized impacts of wildfires on individual properties or communities, resulting in mismatches between insured losses and payout amounts.

- **Regulatory and legal frameworks**: The development and implementation of parametric insurance products for wildfire risks in Europe are subject to regulatory oversight and legal considerations. Regulatory barriers, licensing requirements, and compliance standards may vary across jurisdictions, complicating the process of designing and offering parametric coverage solutions. Additionally, legal challenges related to contract enforceability, liability issues, and dispute resolution mechanisms can impede the widespread adoption of parametric insurance for wildfires.

- **Affordability and accessibility**: Parametric insurance products must be affordable and accessible to a wide range of stakeholders, including large facilities, businesses, and governments, to effectively address wildfire risk exposure. However, the cost-effectiveness of parametric coverage may be influenced by factors such as premium pricing, coverage limits, and reinsurer capacity constraints, limiting its availability to vulnerable populations and underserved regions.

In addition, there is an important concept that is the asset owner risk perception. The insurer proposes a compensation rate or pay off. However, in some cases the risk perception from asset owners can be very different among owners with similar assets value. For instance, as concluded in the innovative action 3.3 of FIRE-RES, forest owners which do not obtain any economic benefit from the forest consider that it is not worth insuring the forest. Therefore, we can conclude that forest exploitation with economic benefit may increase the number of insured forest surface and maintained forests.

4. What do insurers prefer?

This section looks at the requirements for the design of parametric products by leveraging insights from key stakeholders who might become users of parametric insurance modelling instruments. The methodology originally envisioned for this task was based on "co-creation workshops with renowned international brokers and insurance representatives to disclose their requirements for the parametric products to be designed." However, recognizing the potential limitations of such an approach, particularly in the competitive landscape where these industry players operate, Mitiga opted to expand the methodology. This resulted in a comprehensive four-part approach based on design-thinking techniques aimed at fostering transparency, pooling ideas, and identifying opportunities from diverse perspectives.

Having a multi-pronged approach is also in line with design thinking techniques, which prescribe different routes to unveil the needs and aspirations of users. In the famous words of Henry Ford, who invented one of the first automobiles, "If I had to ask people what they wanted, they would have said, a faster horse." Indeed, having a menu of user-centric strategies is critical to extract valuable insights from a diverse range of users and distil trends from isolated preferences. To this end, Mitiga has collected primary data by engaging in:

- Internal insurer requirement workshop and surveys: An initial step involved conducting internal workshops and surveys with Mitiga staff working with insurance stakeholders or in risk modelling to unpack the goals and preferences of stakeholders, guiding discussions with prospective users and internal teams.
- Focus groups with insurers from Living Labs: Two focus groups were organized, utilizing the FIRE-RES living labs (LL Catalonia and LL Aquitaine, both in early 2023) environment as a backdrop. Based on a semi-structured interview guideline, this exercise fostered collaborative discussions and hands-on exploration of potential parametric product features and functionalities.
- Direct conversations with insurers: Extensive direct conversations were held with 14 stakeholders from a diverse array of companies, facilitating a deep understanding of their specific needs, challenges, and aspirations regarding parametric products.
- Dedicated surveys: Building on the earlier insights, a targeted survey was developed and shared with multiple identified users to solicit more in-depth feedback and insights, helping to shape the direction and requirements of the desirable parametric product. The survey was sent to 10 different carriers, mostly from Europe, UK, and one from the US.

Through this approach, this section provides an overview of the user needs and requirements for the design of parametric products, ensuring alignment with stakeholder expectations and industry best practices.

4.1. Internal user requirement workshop

In the process of discerning the potential user base for an insurance product tailored to wildfires, in May 2023, Mitiga held an internal workshop aimed at crafting a user-centric roadmap to pinpoint key motivations and target demographics for the development of a wildfire parametric product. The workshop served to understand existing knowledge and separate assumptions from evidence when it comes to user requirements. This is important to avoid building products that nobody wants or needs and craft solutions that do not resonate with end-users.

The internal workshop convened experts in wildfire and insurance, along with strategy and business leaders at Mitiga. The first step was to try to understand the motivation behind end-users to want to adopt any type of parametric product for wildfire in Europe. Insights generated were divided into buckets ranging from *opinion* to *partial information* all the way to *having evidence to back it up* (Figure 7).

Figure 7. Results from internal workshop on user motivations for insurance mechanisms for wildfires.

In trying to understand who the users of a potential insurance product for wildfires, the team felt that the motivation to seek insurance against wildfire would be initially driven by neglect (not doing anything about it) and then panic (following a major fire, where significant losses take place). The team also believed distributors and large holdings, such as hotels, could be potential primary purchasers of wildfire insurance, contrasting with manufacturers who may exhibit lower propensity due to thin profit margins (e.g., targeting a supermarket chain rather than the agriculture sector).

This observation was reinforced by insights gathered during one of the consortia meetings, where forest owners emphasized the financial strain felt by producers, especially considering that there's no horizontal insurance solution that would look at fire along with other perils like hail or drought. This last fact remarks the paradox of having an insurance for only some perils, while wildfires may be included using different or additional insurance solutions. In addition, anecdotal evidence suggests that some industries are currently left without support/coverage in case of business disruption.

The team had some data to suggest that **the problem (i.e., more fires/limited coverage) will continue to increase in time.** Feedback from conversations with Mitiga's clients and prospects in the insurance sector suggests increasing interest in closing the protection gap in wildfire coverage in Europe. However, the **lack of adequate wildfire models in Europe may be a current roadblock.**

The team has evidence that some **markets/lines of businesses are indeed currently being insured against wildfires in Europe** (although these do not follow a clear pattern in every country). Culturally, **some countries still rely on the government to bail them** out instead of managing the risks directly via insurance coverage. This situation may change as wildfires (and their associated losses) increase in frequency/severity.

The workshop facilitated a nuanced understanding of user perspectives, pinpointing evidence gaps and avenues for further exploration. Recognizing insurance carriers' pivotal role in gauging market appetite, subsequent efforts focused on direct engagements to validate assumptions and ascertain their specific requirements and aspirations.

4.2. Focus groups with users from Living Labs

Mitiga organized **two focus groups with the Living Labs** in the context of FIRE-RES as a data collection approach that allows to further deepen our understanding from a user perspective and the persona associated with the potential insurance product, particularly from the insurance carrier perspective. Persona is an archetype developed to represent a typical user or customer of a product, service, website, or system. They are based on research and data collected about real users and help teams design and develop products and services that are more user-centered and tailored to the needs of their target audience.

Focus Group 1:

The focus group, held in January 2023, aimed at shedding light on the intricacies of insurance coverage in forested areas, particularly in the region of Aquitaine, France. Participants included representatives from the Mediterranean Forest Ecology Research Unit of INRAE (researchers), Mutual Initiated by South-West Foresters (MISSO) (insurance carrier), European Institute of Planted Forest (IEFC) (research-forest managers interface), and Mitiga (modeler).

During the session, it became clear how **forest lands in Aquitaine are relatively well insured,** with approximately 40% of their productive area covered by various insurance schemes. Key insurers identified during the discussions included MISSO, XLB, and Sylvassur. MISSO emerged as a significant player, having encountered significant events such as storms and wildfires, resulting in substantial payouts. Despite these challenges, MISSO expressed intentions to expand its coverage and implement novel commercial strategies to mitigate risks effectively.

Regarding coverage options, the focus group highlighted **considerations for both fire-only and multi-risk insurance,** accommodating the diverse needs of large and small landowners alike.

Risk concentration, perception issues, regulatory complexities, and the availability of state aid (ultimately coming to the rescue of non-insured stakeholders) were seen as hindrances to the development of insurance coverage. To counter these challenges and foster development, potential **strategies such as risk diversification, finer risk modelling, and risk pooling** through unions were discussed, extending beyond the boundaries of the area of the French Forest.

In terms of future developments, MISSO expressed interest in exploring **advanced risk models like Firelihood to enhance MISSO risk assessment capabilities.**

Moving forward, key actions stemming from the workshop include further **exploration of risk models and fostering collaboration with research institutions.**

Focus group 2:

The focus group held in February 2023 in convened a diverse group of participants, including representatives from Blat Seguros (insurance carrier), the Catalan Forest Science and Technology Centre (CTFC) (research), and Mitiga (modeler), with the aim of delving into the complexities of insurance coverage in forested areas.

Blat Seguros is a key player in the Catalan (and Spanish) insurance landscape with a longstanding history in offering insurance products for agriculture, livestock, and forests. They introduced their first forest insurance product in 1994 in response to the aftermath of severe fire seasons in Catalonia. Despite challenges, Blat Seguros has a commitment to expand coverage.

Discussions showed the **relatively low penetration rate of forest insurance in Catalonia,** with various factors contributing to this trend. One significant barrier is the **lack of awareness and understanding** among private forest owners, compounded by a **historical mistrust of insurance** and a **perception that forests hold little marketable economic value. Regulatory complexities, inheritance issues, and gap risk mitigation** measures have also hindered the uptake of insurance policies.

The session also explored the role of other insurers and reinsurers in the market. **Blat Seguros currently operates without direct competition in the forest insurance sector, with Mapfre providing backing for their policies.**

Blat Seguros offers **multi-risk insurance covering wildfire, wind, and snow, with payouts tailored to individual contracts and deductible rates ranging from 10% to 20%.** Annual renewals typically occur in April or May, with no new contracts issued during peak wildfire season.

The discussion also touched upon alternative risk management strategies, including parametric insurance and risk pooling through cooperative insurance models. In the cooperative insurance models and overarching entity will involve a set of owners becoming a single entity and asset for the insurer, also known as a collective insurance model. **While parametric insurance was deemed unsuitable for wildfire risks due to basis risk concerns,** the concept of collective insurance models (cooperative) was considered a potential avenue for reducing costs and diversifying risks.

Blat suggested continued outreach and education, regulatory reforms to incentivize insurance uptake, and exploration of innovative risk management solutions to bolster resilience against forest-related risks.

Minutes from each workshop have been shared internally and can be provided upon request.

4.3. Direct conversations with users

Throughout 2023, Mitiga has engaged in several bilateral interviews with multiple representatives from renowned international brokers and insurance representatives to confirm the assumptions and trends seen to date (outputs from the internal workshop and focus groups). Accounts included in these conversations include Gallagher Re (representatives from both North America and Europe); Munich Re (Europe); Swiss Re (Europe) AXA XL (Global); TransRe (Global); Howden (Pakistan); Allianz (Europe); and Willis Tower Watson (Global).

Key takeaways include:

- **There's an overall level of interest from insurance carriers to explore wildfire insurance models**, even when these companies already have in-house models. As wildfires become more frequent, severe, and unpredictable, and losses multiply; most representatives from insurance carriers we spoke to are increasingly aware of the limitations of their existing models in accurately assessing and managing this type of risk.

- **Going beyond annual forecasts**. Traditionally, the industry has relied on annual risk models to gauge potential liabilities and set premiums. However, the evolving nature of environmental risks, exacerbated by factors such as climate change, has prompted a shift in perspective. Many of the insurance companies we spoke to increasingly recognize the importance of incorporating seasonal forecasts into their risk models, acknowledging that wildfire risk can vary significantly throughout the year. A few insurance companies are also beginning to incorporate short-term forecasts into event response strategies and seeking to enhance their ability to anticipate and mitigate potential losses in real time. In addition, there is a growing interest in expanding the traditional annual coverage to multi-years (i.e., multi-year seasonal forecasts), where resets of those policies consider the occurrence of fires over the period of the policy.

- **Co-development yes, but most prefer ready-to-use models**. While some companies show interest in co-development opportunities for risk models, most prefer jumping on ready-to-use models.

- **New trigger information:** Companies are increasingly opening to satellite technology providing data for trigger designs, the same holds true for aerial imagery through planes or drones. These newly available data sources allow for new types of triggers.

- **Wildfire forecasting and drought analysis**. As fueling conditions for wildfires become quite observable with analysis of how dry the terrain is and how much fuel is on available, market participants are increasingly interested in forecasting to be able to reduce the moral hazard and include obligatory mitigation measures (i.e. fuel management in vegetated areas and building maintenance) into the conditions of insurance coverage. Ignition points are very much human-driven, in some areas to be around 96% (*Wildfires in the EU: 2022 Was the Second-Worst Year, a Warning from a Changing Climate*, 2023).

- **Availability of historical data sets for pricing and model validation**. The insurers have had an increasing request for historical data sets of wildfire events and datasets in general to validate models and apply actuarial methods. The availability of better and more cohesive data sets will enable better pricing.

- **Analysis of local risk, mitigation, and suppression measures**: For many local events fire brigades and local disasters response teams have processes in place to stop fires, thus achieving less wildfire losses. In addition, the usage of mitigation measures and avoidance of moral hazard is of utmost importance. Especially regarding community-based insurance schemes, there is a need to align interests of adjacent policyholders.

- **Wildfire as the peril with the largest trends**: Wildfire is currently hard to price based on a parametric trigger itself, as the basis risk is hard to gather. Wildfire is the peril with significant trends based on climate change mostly. The increasing frequency and severity mean that models based on historical data used for pricing are not accurate. The implementation of seasonal information can provide a solution to this problem. Indemnity triggers (i.e., the models/functions/methods that trigger the payout) reduce the basis risk and continue to be the dominant solution to be replaced.

4.4. Dedicated surveys

Continuing the momentum from prior user engagement initiatives and research endeavors, Mitiga embarked on a new phase aimed at refining assumptions and bridging the gap between user needs and product requirements. This phase involved the deployment of targeted surveys crafted by Mitiga to extract insights from stakeholders within the insurance and broker sectors.

The survey was structured to preserve anonymity, providing respondents with a safe space to express their opinions candidly and without the burden of representing their respective organizations. Each organization could have multiple respondents to ensure diverse perspectives and a comprehensive view of the industry landscape.

To foster transparency and encourage open communication, Mitiga aggregated the survey results. This approach not only ensured confidentiality but also facilitated the unbiased analysis of data, enabling Mitiga to extract actionable intelligence crucial for shaping the development of its products and services.

The survey was shared with representatives from renowned insurance and reinsurance companies (remaining anonymous). Multiple automatic ‘undeliverable’ messages came back and only 5 respondents completed the survey to date (Mitiga will continue the outreach in the weeks to come).

Given the small sample size, results should be interpreted with caution as purely exploratory. However, they are still relevant, especially given the similarity of responses.

- All but one respondent indicated they **do not currently have a wildfire model**.
- All expressed preference for models that could be used for pricing policies **annually**. However, there was also limited interest for seasonal (6-9 months) and even 2-3 years and 10 years' time ranges.
- Having the **probability of burned area** was considered on average relevant (60% considered very relevant).
- Having the **probability of ignition** got mixed reviews, perhaps because of the way the question was formulated. Respondents may have assumed this was a pre-condition for the burned area probability (question asked before). Or they could have interpreted as whether the probability of ignition would be used as a trigger.
- All considered data from **NASA, Copernicus, and national datasets are acceptable** for use in wildfire insurance modelling.
- All required a **validation or quality assessment** procedure despite using datasets with coarser resolution. This entails some form of evaluation or analysis of the pricing model of a triggering function against some observed data considered as ground truth (e.g., remote sensing).

- Among the information required for an effective insurance solution in wildfire risk management, all coincided with the need for **(i) burned/not burned areas; and (ii) fire intensity**. The latter requires further clarification, as this feature could be interesting for insurance purposes (e.g., to determine size of payouts) but may not be a critical feature of parametric instruments.
- 60% of respondents indicated that they would use a **model based on hazard modelling** only (without the loss perspective through a vulnerability module).
- 67% indicated **remote sensing as a potential parametric trigger** in wildfire and 80% would accept **a delay of up to 2 weeks in remote sensing** for a trigger for a parametric risk transfer.

Additional recommendations included:

"Coming from a reinsurance perspective, we're interested in probabilistic losses, so we'd want to see a stochastic catalogue representing tens of thousands of year-samples of fire risk in the current climate. We'd want to see that risk not just be a hazard map but also individual stochastically generated fire footprints. We'd want to link that to vulnerability to a property being burnt, vulnerability to smoke, and vulnerability to business interruption. Then we'd ultimately want to know what a likely average annual loss due to fires might be, and what worst-case scenarios might look like (e.g. event with <0.5% likelihood of occurring in a given year). We're more interested in understanding the underlying risk to manage the losses arising from worst-case outcomes rather than managing risk from an individual ongoing or forecast event. We'd also be interested in climate change perspectives as warming and drying in some regions combine with changing fuel landscapes to increase risk."

And...

"The capability to take into account resilience, such as ecological management, in the pricing. Being able to show the client their risk profile with and without the savings."

5. What does the insurance industry require?

The previous section explored the needs and requirements of a user of a wildfire insurance instrument. Before distilling these insights to create the parameters of a wildfire risk model to serve as a parametric insurance instrument, it is not enough to understand user needs. It's also worth understanding the general requirements of the insurance industry itself.

The parametric insurance method can be a potential candidate method for wildfire insurance. It can provide fast liquidity once a trigger is met and can be combined with pooling arrangements if required. It can be used to cover urgent damage thanks to its fast payment nature. Besides, parametric insurance can be used to promote the reduction of losses on the insured and the insurer's side.

The insurance industry requires a set of characteristics that must be in place to issue parametric instruments, including:

- **Reliable data** for trigger events and loss assessments **trusted and preferably accessible** by all parties involved. However, obtaining comprehensive and up-to-date data on wildfire risk exposure, historical wildfire patterns, and environmental factors in Europe can be challenging due to inconsistencies in data collection methods, incomplete historical records, and varying data standards across regions. In most cases, only the quality assessment can be done and not validation. This is a remarkable point when designing fire modelling mechanisms at very high-resolution datasets that are scarce or directly require expensive fieldwork. In addition, modelling requires a wide variety of datasets coming from diverse sources and data. However, it is accepted that if the result is properly validated, the methodology is suitable for such application.
- **The capacity to capture the nuances of the complexity of wildfire**, including climate conditions, vegetation types, topography, and human activities (which are a dominating factor in wildfire risk). However, the dynamic nature of wildfire behavior and the unpredictability of ignition sources make it difficult to develop standardized parametric models that effectively capture wildfire risk variability across different regions. Uncertainty or lack of models and data to quantify risk continues to be one of the reasons that slow down the development of insurance coverage. Uncertainty in most cases is not even quantified.
- **Clear and objective trigger mechanisms** to determine payout eligibility. For wildfire risks, defining reliable triggers based on parameters related with wildfire occurrence and fire spread behavior such as wind speed, temperature, humidity, or satellite imagery, which can pose challenges due to the inherent uncertainty and variability of wildfire behavior.
- **Be able to address spatial and temporal aggregation of wildfire risks**. Large-scale wildfire events can impact multiple insured parties simultaneously, leading to

systemic risk exposures and potential liquidity issues for insurance providers. Moreover, parametric contracts may not capture the localized impacts of wildfires on individual properties or communities, resulting in mismatches between insured losses and payout amounts. In general, the spatial and temporal aggregation of wildfire risk data should be sourced from a neutral entity, independent of the insurance contract and without vested interests. This data should be accepted by all parties involved in the contract. Typically, public organizations or well-established/accredited entities offer fire monitoring methods that fulfill these criteria.

- **Pay attention to regulatory oversight and legal considerations**. State intervention has contributed to a change of behavior regarding wildfire damage. In France, for example, the government paid 500 million euros to cover wildfire losses. The government is now introducing tax exceptions to promote insurance coverage. Moreover, in response to the German courts, the Court of Justice of the European Union ruled that a group of insurance policyholder may be subject to provisions of the European Union Insurance Distribution Directive (IDD). Therefore, the group requires authorization even when the policyholder is not directly involved in the activity (EUR-Lex - 62020CJ0633 - EN - EUR-Lex, n.d.). or it would require the figure of an insurance intermediary to solve the "improper policy" holder figure (*Directive - 2016/97 - EN - IDD - EUR-Lex*, n.d.). This directive makes it harder for small owners to pool risks via syndicates. In the case of Catalonia, some insurers only accept assets with an approved forest management plan promoting measures for risk reduction. Among the ones that have these plans, only 2% is insured and there is publicly available coverage of the amount forest surface with an approved forest management plan (Cabrera, 2022.). There are subsidies for insuring forests released by the Catalan government with the requirement of the approved forest management plan that promotes insurance coverage.
- **Affordability and accessibility** to a wide range of stakeholders, including large facilities, businesses, and governments, to effectively address wildfire risk exposure. However, the cost-effectiveness of parametric coverage may be influenced by factors such as premium pricing, coverage limits, and reinsurer capacity constraints, limiting its availability to vulnerable populations and underserved regions.

6. Translating user requirements into parameters for wildfire risk models for parametric instruments

Translating user requirements into a wildfire model to be used for parametric instruments can be challenging. Confronting user needs with technical feasibility and affordability requires a balancing act. Furthermore, the very nature of wildfire is heterogeneous, with a fire event considered normal or average for a given location, and severe or mild for another area.

In FIRE-RES IA 3.3 we propose a methodology that can be used for parametric insurance. This proof of concept will be tested in one region in Spain and in Portugal to verify the technical feasibility of the model. This will help assess the quality of the results produced by the proposed structure in the pilots to study the suitability of the results applied in real scenarios for parametric insurance solutions. The selection of the locations for the pilot project was primarily driven by the availability of publicly accessible data, which is crucial for developing the model and conducting a quality assessment of the model's performance.

The model proposal draft will be flexible and **use ignition data and then simulate ignition probabilities and burnt areas.**

Modelling the probability of ignition is a critical point in wildfire modelling. In Europe, anthropogenic fires account for 92% of the total wildfires. While human behavior is not fully predictable, multiple works have been able to predict wildfire ignition points by showing a correlation with lighting records, distances to roads, weather, and some other infrastructures (Martínez et al., 2009; Mancini et al., 2018; Martín et al., 2018; Catry et al., 2009; Guo et al., 2016; Vilar et al., 2010; Rodrigues & de la Riva, 2014; Gonzalez-Olabarria et al., 2012) .

Wildfire is a complex peril for insurance and ignition points modeling can help with mitigation measures. From a claim's perspective, insurance companies will try to go after the perpetrators of wildfires, hence knowing the origin of ignition is an important aspect of settlements. However, we have no clear indication whether ignition points would be of interest as triggers for parametric instruments. Nevertheless, the model can be instrumental in detecting the simultaneity of ignition points, which can be critical to ensure priority response and support insurance companies to understand trends and quickly calculate risk rewards.

In any case, we will develop the **ignition risk probability as a critical component of the fire spread model.** For that, we will:

1. **Compute the Canadian Fire Weather Index (FWI)** based on ERA5 Land dataset.
2. Apply a **machine learning module to normalize values** (i.e., a FWI value in summer in a southern Mediterranean area is different from in the Pyrenees).

3. **Obtain data** of ignition points for the area of interest.
4. **Post-process datasets** that potentially will contribute to the ignition forecast model.
5. **Evaluate the machine learning model**, following scientific standards to avoid overfitted models and ensure proper training and performance evaluation of accuracy.
6. Develop a framework to **build time series of risk of ignition maps.**
7. Before generating the ignition points, **run statistical analysis of the distribution of the probabilities for the area of interest according to the ignition dataset.** This allows us to estimate the expected number of ignitions, the location, and the time.
8. **Generate ignition points for fire spread.** Since we need to generate points for fire spread ensembles, we may need to generate a given number of ignitions regardless of the number of forecasted ignitions. Fire spread modelling can provide useful information of potential fire behavior that can be used for different purposes. If we reduce the amount of ignition to the forecasted ones, the fire spread ensemble can provide few information. Then, we can generate thousands of ignitions depending on the distribution of the probability ignition risk based on the machine learning model.

If we achieve acceptable accuracy during the model's validation process, the workflow will generate one file containing the risk of ignition for each day. That file can be imagined as a video that shows the risk of ignition. To create the risk of ignition file, we should define a workflow for inference of a model that provides the risk, for instance from 0 to 1, of ignition. The extension of the maps that we are dealing with, combined with the resolution required for the datasets that we received, is in the order of a few meters.

Once we understand how a fire may start, we will then **simulate how it will spread.** This entails:

- The **propagation of thousands of ignition points** with a different probability and processes resulting in an aggregated output.
- These simulations would be based on **RabbitMQ and Kubernetes infrastructure.**
- **Data on topography, fuel, and weather** would be collected and transformed to run each simulation.
- Each simulation would run for **a given domain** (i.e., not the entire area of interest) to allow the downscaling of some variables, like wind or moisture.
- Once the simulation is done, we would **process outputs**, like the time of arrival of the fire front (for the initial testing).
- This time of arrival can be **binarized to burned and not burned and weighted with its probability to happen** (probability of ignition). This last file is the **final output**

of the system and represents the probability of an event happening (i.e., a pixel being burned).

The wildfire model for parametric solutions should consider that the amount of ignition creating by the sampling method will not be constant to achieve a probability of burning which is comparable in time. This means we need to establish a **methodology to define the total number of ignitions to generate during the sampling procedure**. For that purpose, we will explore to compute an overall danger for the entire map for a single day. The **overall danger (OR)** could be described as:

$$OR = \int_0^1 H(p) * p\, dp$$

Where:

- OR is the overall risk.
- H(p) is the normalized distribution of the probability of ignition.
- p is the probability.

The current thinking is to relate the OR with the minimum and maximum number of ignitions we want to simulate for the fire spread simulation engine. The time series generated for the burn probability would be comparable in time and space and thus, suitable to generate **individual stochastic footprints** that can be used to implement risk transfer solutions.

Fire intensity, a crucial metric in understanding the severity of wildfires, holds varying degrees of importance depending on the context of its application. For insurance companies, particularly in assessing potential payouts for insured policies, fire intensity plays a pivotal role. The higher the intensity, the greater the potential for widespread damage, leading to larger financial liabilities for insurers. However, in parametric instruments designed for rapid response and efficient risk management, fire intensity may not hold as much significance, and **may not be prioritized in this proof of concept**.

For a parametric solution, **we will explore a range of trigger options**. This could be done by computing the average risk of ignition for a given area of interest and the number of real ignitions in time. By analyzing temporal data series, we can pinpoint anomalous peaks and establish thresholds essential for the implementation of parametric insurance mechanisms. We will also explore the potential of remote sensing technologies. However, it's important to note that the quality limitations of open-source satellite imagery could pose challenges, potentially impacting the overall accuracy and reliability of our proof of concept.

Considering the diverse inputs from stakeholders and the varying requirements across industries, **the final output will not include quantification of loss**, which is not necessarily required upfront in parametric instruments. In addition, many insurance companies often prefer to perform this quantification themselves, as it can significantly differ based on the insured party's specific needs and level of sophistication of carriers themselves.

However, we will assess vulnerability and exposure, with **forestry as our primary use case example.**

The model will not include the element of mitigation measures or smoke damage. Mitigation measures, although crucial in reducing the severity and impact of wildfires, are highly variable and often dependent on factors such as geographic location, infrastructure, and resource availability. Incorporating these measures into the model would introduce significant complexity and uncertainty, potentially compromising the reliability and efficiency of the parametric solution. Similarly, smoke damage presents a unique challenge due to its variable nature and dependence on specific asset characteristics. Accurately assessing smoke damage requires detailed information about the assets at risk, including their construction materials, ventilation systems, and vulnerability to smoke infiltration. Obtaining this level of specificity for a wide range of assets within the designated area of interest would be impractical and resource-intensive, detracting from the streamlined nature of parametric solutions, especially when the focus will be on forestry.

One of the key aspects of parametric insurance instruments is to keep it simple, so that parametric models can deliver timely and actionable insights without the need for extensive data collection or subjective assessments. This approach allows for rapid response and decision-making, enabling insurers and other stakeholders to effectively manage risks and allocate resources where they are most needed.

7. Conclusions

In conclusion, developing a wildfire model tailored for parametric instruments presents a multifaceted challenge. Balancing user requirements with technical feasibility and affordability demands a nuanced approach. Additionally, the inherent heterogeneity of wildfires, with varying severity across regions, further complicates the modeling process.

This report tried to unpack the different user and industry requirements to establish a parametric solution for wildfires in Europe. We have employed various design thinking methodologies, each offering unique perspectives and insights into the multifaceted needs of stakeholders. However, the evolving nature of the industry demands continuous engagement and dialogue with stakeholders. By maintaining open channels of communication and fostering collaborative relationships with industry experts, we can validate insights gleaned from individual preferences from broader industry trends.

This user-centric foundation served to inform our proposed methodology to model wildfires to feed into parametric instruments. Through pilot testing in regions in Spain and Portugal, we seek to verify the technical feasibility of our approach and evaluate its effectiveness in real-world scenarios. We will also focus on forestry, understanding the need for targeted solutions tailored to specific industries and risk profiles.

Central to our model is the computation of ignition risk probability, leveraging factors such as fire weather indices and machine learning algorithms. While acknowledging the importance of factors such as fire intensity, mitigation measures, and smoke damage, we have opted to exclude them from the model to maintain simplicity and scalability. This decision ensures a streamlined approach to parametric modeling, enabling rapid response and decision-making without extensive data collection or subjective assessments.

Wildfire catastrophe models serve as a robust and well-established pilar for assessing and pricing natural catastrophe risks within the insurance industry. They are commonly relied upon as a framework for facilitating alternative risk transfer on a broader scale.

Effective insurance of risks and their mitigations requires proactive measures. While achieving higher levels of private insurance coverage is desirable, it should be meticulously crafted to foster adaptation and minimize vulnerability to climate-related catastrophes. Insurance policies can promote risk reduction and adaptation to climate change among policyholders, while mitigating moral hazard through impact underwriting.

Reinsurers must seek to actively integrate climate change risks into their risk management strategies to ensure the long-term sustainability of their operations. Additionally, capital market instruments such as catastrophe bonds can complement insurance schemes by providing fast liquidity for reconstruction efforts and transferring risks to investors.

In preparation for contingent liabilities, the public sector should enhance prevention measures for disaster risk management by establishing fiscal buffers such as national reserve funds. Supporting private insurance solutions through public-private partnerships and capital market products is also essential. Governments can play a pivotal role in fostering an active market for catastrophe bonds by reducing issuance costs.

Furthermore, improved measurement of fiscal expenditures related to extreme weather events is critical for effectively managing fiscal risks and enhancing disaster preparedness initiatives.

Addressing these challenges will require a concerted effort from stakeholders across the insurance industry, government agencies, and local communities to enhance risk awareness, improve resilience, and foster innovation in wildfire risk management and insurance solutions. Parametric risk insurance is a good mechanism to help close the protection gap. The development of models for pricing these is a pre-requirement and data serving as a trigger basis are essential.

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