PIISA

Piloting Innovative Insurance Solutions for Adaptation

D3.9: Concept of Climate Change Risk Sensitized Forest Insurances

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Table of contents

List of figures

List of tables

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Executive Summary

Forests in the European Union are facing significant climate-related threats such as wildfires, windthrow, drought, and pest infestations, yet remain largely underinsured. **In Germany**, with **only 1-5% of the national forest area covered by insurance**, the financial risks for forest owners are substantial, threatening both the sustainability and resilience of these critical natural assets.

The Piloting Innovative Insurance Solutions for Adaptation (PIISA) project, funded under Horizon Europe, aims to address these challenges by **developing innovative, climate-sensitive insurance products to de-risk investments in forestry and encourage adaptive management practices**. The PIISA project is a three-year initiative involving 12 partners from five EU countries, including research institutions, meteorological agencies, and insurance experts. It focuses on co-developing climate-resilient insurance portfolios and data-sharing solutions for climate risk and losses. The project is organized into several pilot projects. **The pilot in Bavaria, Germany**, is the focus of this project report, and it aims to develop and test new insurance models **targeting private forest owners**.

As an initial step, **this report is prepared for the partners of the PIISA** and Horizon Europe projects to raise awareness about the project's scope, promote collaboration among the consortium members, and minimize the risk of duplicating efforts within and across related projects. **It is also intended to engage other insurance companies**, encouraging them to feedback into and adapt the project's models for use in different regions and contexts.

The first phase of the pilot (Loop 1), running from December 2023 to February 2025, is centered on creating a climate-sensitive forest insurance product by AXA Climate in collaboration with AXA Germany. The project is **testing various existing and innovative insurance structures**, including parametric and indemnity insurance models, **to determine** the most effective **mechanisms for de-risking forestry investments**. The phase has so far studied **windthrow and wildfire risk models**, leveraging **satellite data** and **historical loss** records **to design and price insurance products tailored to local conditions.**

Early findings indicate that while both **windthrow and wildfire** pose significant risks to German forests, they are also **more feasible for insurance solutions compared to** other threats like **bark beetle infestations and snow damage.** The pilot has made significant progress in modelling these risks and developing tailored insurance products that can help mitigate the financial impact on forest owners, thereby supporting more resilient forestry practices in the face of climate change. The subsequent loops will expand the scope, test broader adoption, and explore the replicability of these insurance solutions in other regions, including the boreal forests in Finland.

The **co-creation process is a key aspect of PIISA**, involving stakeholders in the design, development, and delivery of the insurance solutions. The pilot's first loop focused on co-designing plans and activities with partners and stakeholders, followed by co-development, of localized

knowledge related to wildfire risks, adaptation measures and insurance products, which were iteratively refined based on stakeholder feedback. **This report** outlines the methodology employed, **shares preliminary results** from Loop 1, and **presents the next steps in the project's development.** This pilot, as a part of the overall PIISA project, is paving the way for innovative insurance solutions that can play a crucial role in safeguarding Europe's forests, promoting sustainable forest management, and enhancing climate resilience.

Keywords

Climate-resilience, parametric insurance, climate adaptation, forest risk management, windthrow, wildfire, Germany

Abbreviations and acronyms

Acronym	Description
EU	European Union
FMI	Finnish Meteorological Institute
KPI	Key Performance Indicator
PIISA	Piloting Innovative Insurance Solutions for Adaptation
SWIFTT	Satellites for Wilderness Inspection and Forest Threat Tracking
WP	Work Package

1 Introduction

Forests are recognized as a crucial natural asset both for their biodiversity and climate action potential, as well as the services they provide, such as to fulfil the increasing demand of wood from the construction industry. However, these valuable resources face growing threats from climate change, including fires, pests, diseases, and extreme weather events, making them significantly underinsured. Forests in the European Union are facing a critical lack of insurance cover to effectively combat the challenges posed by climate change. In Germany, for example, only about 15% of private forests have insurance coverage, and there likewise exists a very low national insurance penetration rate, at 1-5% of national forest area (Gardiner, Blennow, et al., 2010). The lack of adequate insurance coverage exposes forest owners to substantial risks and potential financial losses, undermining the sustainability and resilience of forests. This is largely due to a lack of awareness and understanding of natural capital asset insurance, as well as a mismatch between perceived and actual risks. Contributing factors include the high number of smallholder farmers, increasing climate-related risks which elevate forest risks, high insurance premiums due to low insurance volumes, and the reliance on emergency public funding traditionally used for climate-related disasters. These challenges highlight the critical need to address this issue comprehensively. Even in areas where the situation with respect to the health of forests is still optimal, the risk for forests is expected to harshen with climate change. This is, for instance, the case of the boreal forest. In Finland, the shortening of the soil frost period (and the risk for wetter soil) will increase wind damage risk; worsening drought in summer will boost the risk of large-scale forest fires, and the warmer climate in turn heightens the risk of bark beetle outbreaks (Venäläinen, Lehtonen, et al., 2020).

De-risking solutions such as insurance can help attract more interest of public and private investors and encourage forest managers. This project is therefore investigating innovative climate-related forest insurance to de-risk investments in forestry and encourage forest managers to adopt adaptive measures. Insurance can support such risk management and adaptation by enabling forest owners to transfer the financial burden of climate-related risks, such as forest fires, droughts, and pests, to the insurance companies. This reduces the direct financial impact on forest owners in case of damages or losses, encouraging them to invest in risk reduction and adaptation measures. Climate services could further support decision-making and risk management in the context of climate change adaptation by providing access to climate forecasts and projections to forest owners. These owners can subsequently use this information to make informed decisions about forest management, such as prioritizing adjusted planting and harvesting times based on anticipated climate conditions.

PIISA is a three-year Research and Innovation project with climate adaptation and insurance at its core. It is funded under Horizon Europe, and includes twelve partners from five EU countries, spanning research and academia, meteorological agencies, climate risk and sustainable innovative consulting, and insurance experts. The project focuses on co-developing climate-resilient insurance portfolios, and data-sharing solutions for climate risk and losses. Work Package

(WP) 3 is led by the Finnish Meteorological Institute (FMI), and focuses on pilot projects across three ecosystems: Cities and Well-being (Task 3.2), Food and Agriculture (Task 3.3), and Forestry (Task 3.4). This is the first of the two pilots belonging to Task 3.4, related to forests, and is focused on the design and development of innovative insurance models, learning from existing forest insurance schemes. It focuses on Germany as a first location, with our pilot area located in Bavaria, North-West of Munich.

The remainder of this paper is organized as follows: Section 2 provides an overview of the project and its primary objectives, highlighting the need for innovative insurance solutions in the context of climate-related risks for forests. Section 3 details the approach and methodology employed in the pilot, focusing on the co-creation process and the structure of the three loops designed to refine and test insurance products. Section 4 covers the first loop of the project, showcasing the iterative design and development process, with an emphasis on the windthrow and wildfire models. Finally, Section 5 outlines the next steps and upcoming work planned for the subsequent loops.

2 Project Overview and Objectives

The PIISA project seeks to actively engage forest owners and managers, forest insurers, and other relevant stakeholders active in the forest industry in exploring various climate change risk sensitized forest insurance products designed to meet their needs. The primary objective is to explore and develop insurance solutions that provide comprehensive coverage for key climate-related hazards, including windthrow, wildfires, drought, and pest infestations like bark beetle outbreaks. The pilot will investigate the feasibility and effectiveness of different insurance structures, including indemnity, parametric, hybrid, and carbon credit insurance models (Table 1), to determine the most feasible, applicable, and scalable mechanisms for de-risking investments in the study region. The project will also explore the potential of carbon credit insurance if relevant.

Type of Insurance	Description
Indemnity Insurance	Compensates the insured based on the actual loss or damage suffered. A loss assessment is conducted after the event (e.g., wildfire), and the payout is calculated accordingly. This can take time as it requires a thorough damage evaluation.
Parametric Insurance	Provides payouts based on predefined parameters or triggers (e.g., rainfall levels or wind speed), regardless of the actual damage. It allows for quicker payouts since no loss assessment is needed, but the payout might not reflect the exact loss. Other advantages include transparent methodologies, and the possibility to assess how much the management of an area impacts the risk and price.

Hybrid Insurance	Combines elements of both indemnity and parametric insurance. Part of the payout is based on triggers (like parametric insurance), while another part is based on actual damage assessment (like indemnity insurance), offering a balance of quick payouts and accurate compensation.
Carbon Credit Insurance	Covers risks related to carbon credits, such as project failure or underperformance in carbon sequestration. It ensures that the value of carbon credits, which represent reduced or removed emissions, is protected for forestry or other environmental projects.

Table 1: Overview of Insurance Models

In Loop 1, the project will focus on Germany, targeting private forest owners to develop and test new insurance models that consider both current and evolving climate risks. This phase will assess the feasibility for rapid damage assessments, providing a faster and potentially more effective alternative to traditional indemnity insurance. While the remaining loops will explore expansion and replicability of the designed schemes, the focus of this report is on Loop 1.

3 Approach and Methodology

The pilot will be implemented in three loops, each with a specific aim, as listed below. This document will only cover the process and results of the first loop.

1. Loop 1 (December 2023-February 2025): This loop focuses on creating a climate-sensitive forest insurance product in Germany in close collaboration with AXA Germany, primarily targeting private forest owners. It involves identifying current forest insurance clients who fit the profile, considering factors like evolving climate risks and adaptation measures planned and implemented by the clients. The risks addressed include forest fire, drought, and pests, such as the bark beetle. Various insurance products, including parametric insurance, will be tested to cover these risks. The project will assess evolving risk levels, inform clients of future projections, and analyze adaptation levels. Engaged forest owners will be offered different insurance variations in coverage structure and pricing, considering threshold levels, adaptation level discounts, and risk-sharing options. The focus of this research exercise is to provide a basis for and pave the way for subsequent innovative insurance products in the market. The results of this exercise as a part of PIISA will be publicly available.

2. Loop 2 (February 2025 to March 2026): This loop involves a comprehensive test series for broader uptake will be designed and carried out. This phase will involve extensive surveys to assess levels of interest and key characteristics of forests and forest owners

driving new insurance acceptance probability. Also, interactive choice experiments will be conducted with local organizations' support to refine and tailor the insurance products.

3. Loop 3 (November 2025- March 2026): This loop includes surveys to be conducted to assess the potential for the adoption of new forest insurance schemes in the Boreal region. A webinar will be arranged to introduce the new insurance schemes and share insights gained from Loops 1 and 2. This webinar will be attended by a group of stakeholders identified by Tyrsky, FMI, and LocalTapiola. After the webinar, a workshop will be organized to explore how insurance products can encourage forest owners to take measures to reduce current abiotic and biotic hazards, and plan adaptation actions against intensifying hazards in the future. Replication and scalability will also be studied in other European regions such as Finland.

Co-creation is one of the key development methods used in piloting. Co-creation in the PIISA project follows a structured approach, with each loop organized into three distinct phases: Co-design, Co-development, and Co-delivery. In the Co-design phase, stakeholders collaborate to define the objectives, activities, and scope of the pilot, refining the understanding of problems and needs. The Co-development phase involves jointly developing knowledge, tools, or solutions, incorporating stakeholder feedback iteratively. Finally, in the Co-delivery phase, these solutions are applied and tested with stakeholders and end-users, gathering feedback for further refinement. Each loop in the process undergoes these three phases, ensuring continuous collaboration and improvement.

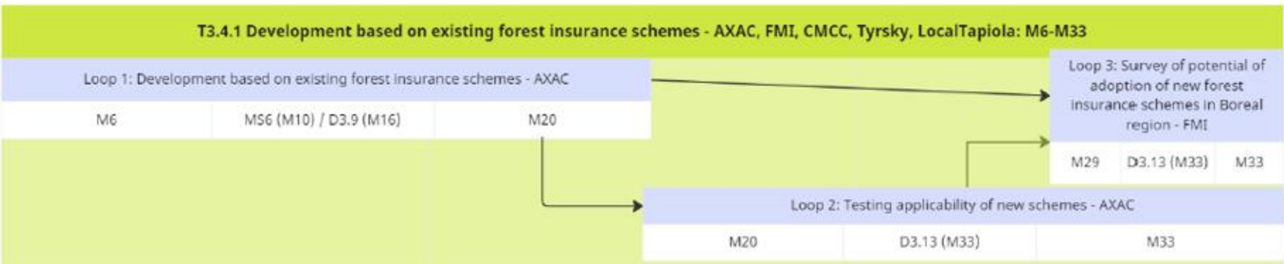

Figure 1: Overview of the different Loops

4 Loop 1

4.1 Overview

Table 2 provides an initial project overview:

<table>
<tr><th colspan="3">Overview</th></tr>
<tr><td>Period</td><td colspan="2">Between December 2023 and February 2025</td></tr>
<tr><td>Objectives</td><td colspan="2">Loop 1 consists of:
Securing the pilot areas by onboarding the local stakeholders
Gathering information necessary for the co-development phase: review of available forest insurance products (from AXA Climate and AXA Germany) and identification of potential limitations for the forest managers
Estimation of parametric pricings on the pilot area with “classic” structure on wind, wildfire, pest, etc.
Wrap-up and gap analysis between what exists today and the inputs coming from WP 1 and 2.</td></tr>
<tr><td>Methodology</td><td colspan="2">Interviews and co-designed workshops with the pilot stakeholders (i.e. German partner, AXA Germany, Local Tapiola, Tyrsky, FMI, etc.)
1 online workshop per month is anticipated to carry on with Loop 1. The agenda of each meeting and content will be sent one week in advance so all participants will have time to review and make comments.</td></tr>
<tr><td>KPIs</td><td></td><td>Target value</td></tr>
<tr><td>KPI 1</td><td>Number of plots studied</td><td>3-5: Studied 4</td></tr>
<tr><td>KPI 2</td><td>Number of insurance design realized on the pilot areas</td><td>8 (i.e. 2 per peril): Studied 4/8</td></tr>
<tr><td>Support expected from the other WPs</td><td colspan="2">The inputs coming from the other WPs, and the delivery date to be integrated into the pilot development, for instance coming from the following tasks:
Task 1.1: mapping review and assessment of insurance solutions regarding forest asset across EU Member States
Task 2.2: This task will translate the new end-user needs identified in both WP1 and T2.3 into sound scientific and technical requirements for service development
Task 2.3, which involves co-developing services for the pilots. This analysis encompasses mapping future climate risks and identifying potential adaptation measures for the forestry sector to integrate into the insurance</td></tr>
<tr><td>Partners involved</td><td colspan="2">AXA Climate, AXA Germany, LocalTapiola, FMI, Fondazione CMCC, Amigo Climate</td></tr>
<tr><td>Stakeholders involved</td><td colspan="2">Arco-Zinneberg'sches Forstamt (German forest partner)
AXA Germany
For future loops: Members from SWIFTT EU project working on the bark beetle model, and other stakeholders identified as the project progresses</td></tr>
</table>

Output	• Gather information on existing insurance products (e.g.: AXA Germany for Indemnity and AXA Climate for Parametric) • Evaluate and compare the different existing options for the pilot plots: guarantees, structure, pay-out, premiums. • Alignment of partners on the design phase: which perils will be integrated in the construction phase, when, what tests are to be conducted, how adaptation solutions will be integrated into the product

Table 2: Overview of Phase 1

4.2 Pilot location

The pilot location is situated in Bavaria, North-West of Munich, Germany. The indicative plots are marked in red in Figure 2. The area includes 3 parcels or blocks of about 500 ha, with an additional 500 ha consisting of several smaller compartments between 5 to 90 ha. Forests in Germany are the focus of this study as between 2000 and 2023, Germany experienced an 11% decrease in tree cover (Global Forest Watch, 2023). Turning to more recent changes, tree loss is found to be equivalent to 5% of Germany's forested area as observed from 2018-2021 (Figure 3), with an estimated ~500k ha of forest die-off with removal (DLR, 2022). Key triggers leading to this decrease in tree cover include intensive periods of heat, drought, storms, and windthrow, leading to secondary, compounding damage from wildfire and pest infestation.

4.3 Partnerships

This pilot involves a partnership between AXA Germany, Germany's largest insurer for forests with ~1.3 million hectares under coverage, and Acro-Zinneberg, a private forestry enterprise operating across Central Europe (Bavaria, Austria, and Czech Republic).

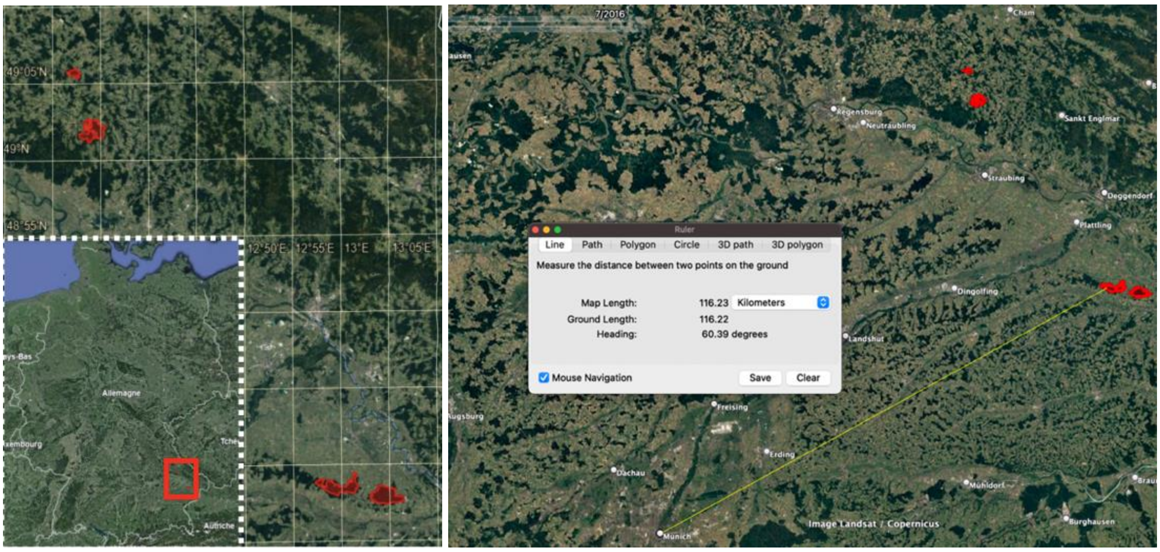

Figure 2: Pilot areas

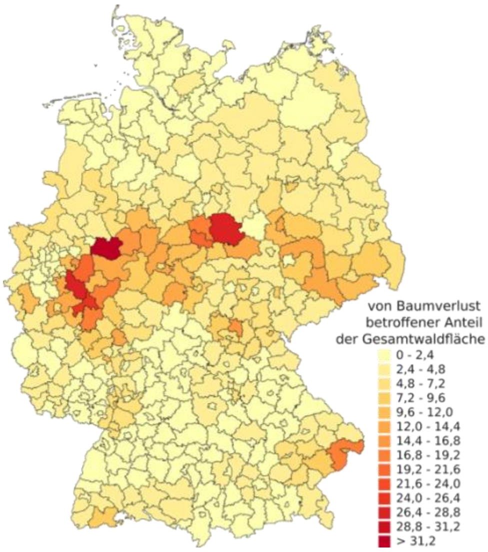

Figure 3: Proportion of total forest area affected by tree loss, 2018-2021 (%)

4.4 Existing insurance products

The project commenced with a study and overview of existing insurance products in the European market as a basis for the new design, as can be seen elaborated on in Table 3.

Parametric Insurance Products developed by AXA Climate	
Wildfire Insurance	A satellite-based insurance solution that detects in real-time areas affected by wildfires and triggers the payout
Tree Emergence Insurance	A satellite-based solution that detects an anomaly in the growth of young trees due to any cause (drought, insect outbreak, etc.)

Windthrow Insurance	A satellite-based solution that detects uprooted trees as a result of high winds
Indemnity Insurance Products developed by AXA Germany	
Forest Fire Insurance	Insurance cover in the event of fire, lightning, or explosion for forest stands
Forest Storm Insurance	Insurance cover in the event of destruction of damage to forest stands due to the direct effects of storm events
Forest Owner's Liability Insurance	Insurance cover for personal injury and other property or financial loss damage for compensation claims that may arise

Table 3: Overview of existing parametric and indemnity insurance products for forest stakeholders.

4.5 Scoping of the risks

An initial scoping exercise was then conducted with Forst Arco-Zinneberg to understand the perceived risks and primary considerations. Initial data considerations indicated good data availability in German forests regarding tree species, diameter, height, and age. The perceived risks are summarized in Table 4.

Perceived risks (Biotic and Abiotic)	Existing Insurance Products	Planned Project Activities
Windthrow damage (high incidence)	Yes, parametric and indemnity	Comparison of the two existing structures for Germany plots. Identification of the wind models that could be used
Snow (medium incidence)	No	Within multi-peril
Wildfire damage (low exposure and risk of damage to Arco Zinneberg)	Yes, parametric and indemnity	Comparison of the two existing structures for Germany plots. Low risk
Pest damage (high incidence)	None that are known, but there is a lack of available data, modelling, and coverage options	Identification of the detection models that could be used
Multi-peril	Yes, but out of PIISA's scope (climate risks only)	Exploration within indemnity models
Liability		

Table 4: Overview of Perceived Risks for Forst Arco-Zinneberg

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Through the initial scoping, we found out that for Forst Arco-Zinneberg over the past four years, 7% to 51% of the harvested volumes were affected by windstorms, while 2% to 33% of the volumes were impacted by bark beetle. In light of these considerations, it was proposed to start the design phase studying windthrow damage. As we can see in Figure 4, windstorms are also the leading risk in Europe, making them a top priority for forest risk management (derived from DFDE, 2020). Wildfires will also be studied; though less frequent than windstorms, they still cause 25% of forest loss in Europe, and have increasingly severe impacts due to climate change, further justifying the need for robust insurance mechanisms. While snow and bark beetle infestations pose significant risks to German forests, our focus has been strategically placed on developing windthrow and wildfire risk models due to both their impact and feasibility for insurance solutions. This conclusion was reached due to both data availability as well as precedent of the insurance models for windthrow and wildfire solutions.

In contrast, while bark beetle infestations represent an important biotic threat, especially following disturbances like windthrow, several challenges complicate the development of an insurance solution for this hazard. There is no record of insurance solutions being developed for this threat to date. Furthermore, initial assessments suggest that forest owners may prefer early warning systems over insurance for this threat as a more cost-effective mitigation strategy. These events are also highly influenced by the management practices in neighboring forests, requiring cross-sectoral responses. This, in addition to the fact that outbreaks can persist for several years makes this a difficult threat to insure sustainably. Moreover, current scientific methods struggle to reliably attribute forest dieback to bark beetles using satellite imagery, indicating that the necessary tools for insurance applications are not yet fully developed (Dutrieux, Senf, et al., 2023).

Snow risks, on the other hand, showcase limited market interest, and are often manageable through self-insurance, as suggested by preliminary findings. While we plan to confirm these findings for both snow and bark beetle threats during upcoming work and in Loop 2, for the time being, windstorm and wildfire risks are deemed to present a more immediate and insurable threat, resulting in our focus on these risks for the remainder of the paper.

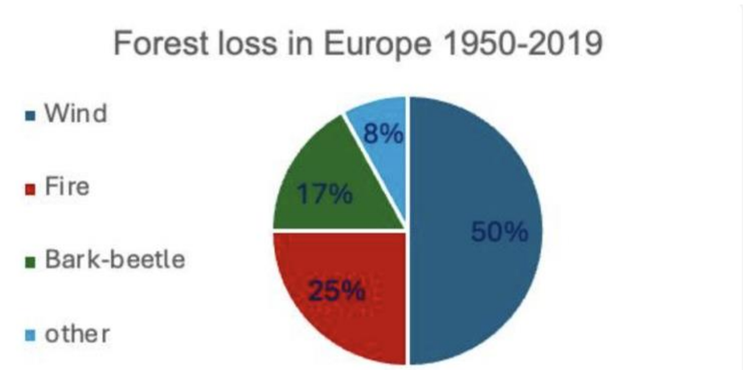


Figure 4: Leading causes of Forest loss in Europe (DFDE, 2020)

4.6 Iterative Design and Development

The iterative research and design process was structured around seven work sessions that were conducted between January 2024 and September 2024. These sessions facilitated continuous collaboration and refinement, allowing the different stakeholders to input and feedback into the design process at every stage, ensuring the overall effectiveness and relevance of the final deliverables. Further details regarding the timeline and workplan surrounding these work sessions can be seen in Table 5.

Date	Type of Activity	Partners Involved	Summary
30.01.2024	Kickoff Meeting	AXA Climate, ArcoZinneberg Forstamt, AXA Germany, FMI, CMCC, Amigo Climate, Local Tapiola, Tyrsky	Pilot kickoff with all pilot stakeholders, to present pilot concept, define each stakeholder's interests, understand potential contributions and development directions.
22.02.2024	Work Session 1	AXA Climate, ArcoZinneberg Forstamt, AXA Germany, Amigo Climate, CMCC	Overview of proposed modelling process and existing insurance models
24.03.2024	Email exchange	AXA Climate, ArcoZinneberg Forstamt	Reception of the mitigation concept note from the local partner
21.03.2024	Dataset development	AXA Climate, ArcoZinneberg	Dataset built and semi-empirical model testing started. Ground truth data collection begins for various perils.
26.03.2024	Work Session 2	AXA Climate, AXA Germany	Discussion on wind insurance in Germany and comparison of an indemnity and parametric pricing with the pilot characteristics
08.04.2024	Work Session 3	AXA Climate, ArcoZinneberg Forstamt, AXA Germany, FMI, CMCC, Amigo Climate, Local Tapiola, Tyrsky	Presented and compared two wind models; discussed remote sensing wind models.
April 2024	Email exchange	AXA Climate, Amigo Climate	Reception of Amigo wind model
16.05.2024	Work Session 4	AXA Climate, ArcoZinneberg Forstamt, AXA Germany, FMI,	Presented wind model integrating adaptation; compared wildfire with indemnity and parametric models.

		CMCC, Amigo Climate, Local Tapiola, Tyrsky	
20.06.2024	Work Session 5	AXA Climate, ArcoZinneberg Forstamt, Amigo Climate	Discussed FAIS summit insights. Presentation of two wind model results, with the second model providing promising results
25.07.2024	Work Session 6	AXA Climate, AXA Germany, Amigo Climate, CMCC	Presented the model update with good initial insurance applicability; discussed data constraints and plot filtering.

Table 5: Work Session Breakdown

The design phase of the insurance product involved the development of a robust statistical model grounded in mechanistic features. The model should be tailored to capture the interactions between forest characteristics and environmental features, as these differ significantly across regions and forests, which, due to their unique characteristics, respond differently to identical stimuli. By incorporating these variables into the model, the insurance product designed can more accurately assess the localized risk and provide coverage that reflects the true vulnerability of each forest. The benefits of parametric insurance allow us to assess this vulnerability and price the product accordingly, overcoming a key problem of indemnity insurance around moral hazard, within which an equal cover is provided to a badly managed or a well-managed forest. Following this, there is often the inclusion of a no claim bonus in the policy, where a client can recover a part of their costs if the policy doesn't trigger. As this is more likely for well-managed forests with adaptation measures in place, this structure further incentivizes appropriate forest management.

Following the model design, a comprehensive database was built to support the insurance product. This database integrates a wide range of data sources, including detailed information on forest and soil characteristics, topographic conditions, as well as different stimuli. Initial database design can be seen in Figure 5. Various data collection protocols were also shared to ensure reliability of data, across a range of criteria including parcels requirements and timelines, technology and tools, and user proficiency and training. Ground truth data collection processes commenced on the different perils to be studied. For example, the description of current forestry techniques, risk management measures and adaptations from Arco-Zinneberg were collected.

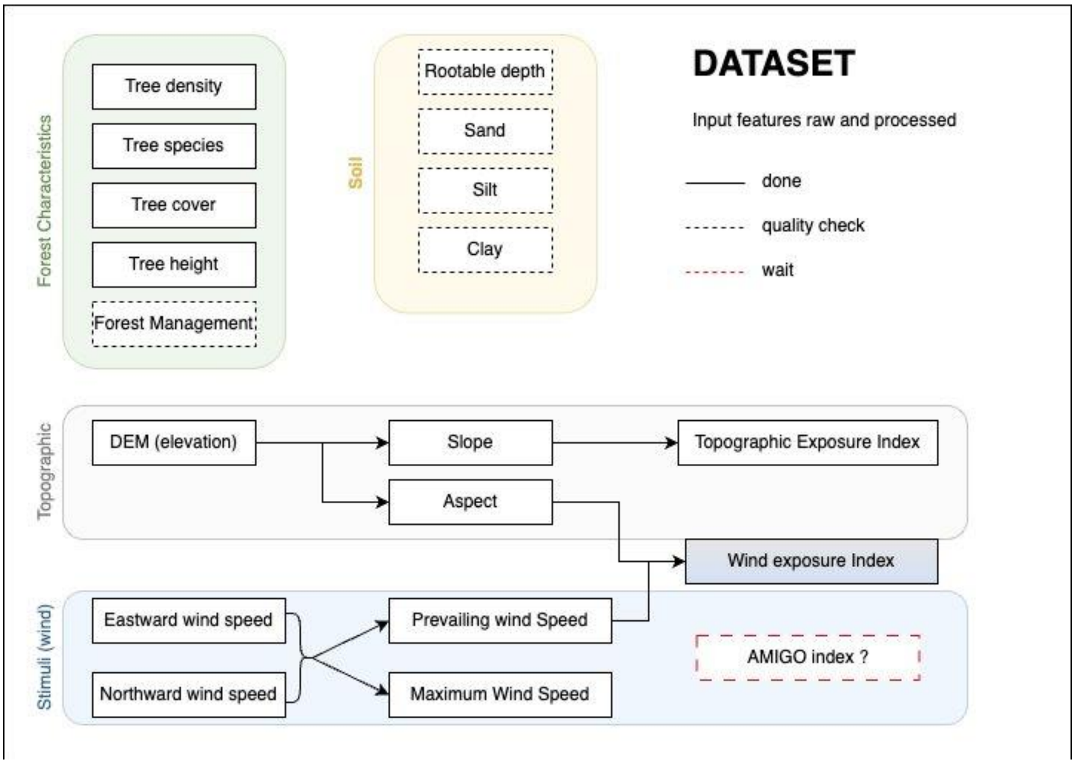
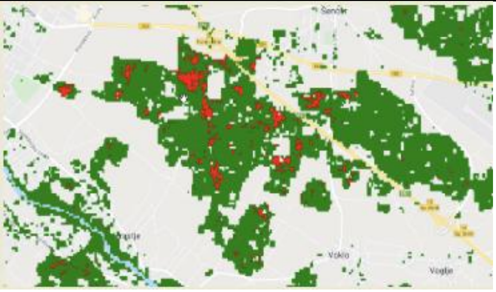


Figure 5: Overview of the database

The general workflow of a parametric set up includes the study of the shapefiles of clients' locations, the simulation historical losses based on satellite imagery, the confirmation of the losses with the client, the risk modelling, and the pricing structure and premium set-up. For the purposes of this pilot, after the initial scoping exercise and understanding of risks, AXA Climate decided to proceed by focusing on Wildfire and Windthrow models, which are detailed in the following sub-sections.

4.6.1 Windthrow Model

Potential windthrow covers for the Arco-Zinneberg Forest were studied, taking into account both AXA Climate's existing parametric model, as well as AXA Germany's existing indemnity model. The similarities and differences of each model are detailed in Table 6.

<table>
<tr><th>Category</th><th>Parametric Model by AXA Climate</th><th>Indemnity Model by AXA Germany</th></tr>
<tr><td>Graphical Overview</td><td>
Detection of windthrow with satellite imagery</td><td>
Tariff contributions<table><tr><th>Age</th><th>Spruce</th><th>Pine</th><th>Hardwood</th></tr><tr><td>0</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>1</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>2</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>3</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>4</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>5</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>6</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>7</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>8</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>9</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>10</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>11</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>12</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>13</td><td>1</td><td>1</td><td>0,5</td></tr><tr><td>14</td><td>1</td><td>1</td><td>0,5</td></tr></table></td></tr>
<tr><td>Definition</td><td>A satellite-based solution that detects uprooted trees as a result of high winds.</td><td>A historical data-based solution that evaluates post-storm damages with a network of field experts</td></tr>
<tr><td>Methodology</td><td>Three models available, to be chosen according to the client’s risk profile and maturity</td><td>Two models available (per cubic meter or per surface area), to be chosen according to the client’s risk profile and maturity</td></tr>
<tr><td>Purpose</td><td>Cover financial losses decided by the client, often cleaning and replanting costs. No loss assessment processes, fast payouts, worldwide feasibility.</td><td>Cover financial losses due to a drop in timber selling price</td></tr>
<tr><td>Insurance Deductible</td><td>Yes, depending on the client’s risk appetite. Often around [2%-10%].
For this study: 50,000€ (<2%)</td><td>Yes, depending on previous damages, risk assessment, and customer requirements. At least 10% of the claim value.
For this study: 50,000€</td></tr>
<tr><td>Insurance Limit</td><td>Yes, depending on the surface covered. Often around [10%-20%] to limit the insurance premium to an affordable price.
For this study: 10%, 861,500€
Rate on Line (RoL): 2.14%</td><td>Could be decided for very large parcels, but not relevant for Germany as the plots are not very large</td></tr>
<tr><td>Value insured</td><td>To be given by the client, value based on a price per hectare. Worldwide, varies around [1000-7000€].
For this study: 1938 ha at 5000 € / ha</td><td>If cubic meter model: € per cubic meter of damaged timber. Often in Germany around [10€-16€].
For this study: 12€ / m3
If surface model: € per hectare of damaged timber Often in Germany around [3000€-6000€]
For this study: 5000€ / ha</td></tr>
</table>

Historical data used for pricing	• ERA5, since 1950 • Sentinel 2, since 2017	Historical events shared by the client. For this study: since 2019
Contract duration	Yearly	1-5 years
Premium Calculation	Depends on the limit, the deductible the value insured, and historical events detected by satellite imagery (and confirmed by the client). For this study: 21,014.31€ (12.20 / ha)	Depends on the age of trees, the species, the value insured, and historical events shared by the client. • For the cubic meter model: [25,116€-22,605€] [1-year-5-year] • For the surface area model: [14,934€-13440€] [1-year-5-year]
Limitations	• Cover parameters and thresholds need to be challenged by business needs and risk appetite for Arco Zinneberg • European satellites do not allow enough historical losses to properly calibrate the model; need for a larger quantity of data to get a good fit • Difficult to evaluate an overall risk, we cannot separate the drivers, therefore we can't simulate effect of best practices in forest management with the bi-temporal model. → It emerges the need to get a semi-empirical approach to include effect of forest and environment into the risk of wind damage into PIISA model	• Depending on the customer's specifications (damage, tree species, age classes, etc.) • In case of an event, indemnity process can be very long (pay-outs are still pending for the 2022 storm, waiting for national foresters' report)

Table 6: Comparison between Windthrow Parametric and Indemnity Solutions

Given the potential feasibility of a parametric insurance solution for wind risk, windthrow models were further explored by the AXA Climate team. This was done through three different approaches, each leveraging distinct data sources, and outlined as follows:

- Bi-Temporal model: It relies on dynamic world data from Sentinel 2, covering the period from 2017 to the present, and is filtered by wind event to cover forest re-establishment. This is the model that was used for the case study, with the key principles outlined below
  - From Dynamic World dataset (Sentinel 2), we have the probability for each pixel (10mx10m) to content a tree.
  - The model evaluates the change in the probability of a tree in the pixel: if there is a storm, the probability there is a tree drop
  - Due to statistical laws, we compute a threshold defining the significant changes corresponding to a forest disturbance
- Continuous Change model: It uses the Landsat collection for data, spanning from 1982 to today. It is also filtered by wind events, to cover re-establishment. This model is not PIISA compliant as it doesn't use Copernicus imagery.
- Parametric loss based on wind index: It could use either ERA5 land data (with a historical range from 1950-today), or the windstorm index data from Amigo Climate. It is filtered by wind events, and covers both re-establishment and financial losses. This model is under construction for Loop 2 of this project.

4.6.2 Wildfire Model

Potential wildfire covers for the Arco-Zinneberg forest were studied, taking into account both AXA Climate's existing parametric model, as well as AXA Germany's existing indemnity model. The similarities and differences of each model are detailed in Table 7.

<table>
<tr><th>Category</th><th>Parametric Model by AXA Climate</th><th>Indemnity Model by AXA Germany</th></tr>
<tr><td>Graphical Overview</td><td>
Detection of fire with satellite imagery</td><td><table><tr><th>Age</th><th>oak/beech</th><th>birch/alder</th><th>spruce/douglas</th><th>pine/larch</th></tr><tr><td>0</td><td>8 000</td><td>3 000</td><td>4 000</td><td>5 000</td></tr><tr><td>1</td><td>8 140</td><td>3 133</td><td>4 140</td><td>5 104</td></tr><tr><td>2</td><td>8 300</td><td>3 257</td><td>4 308</td><td>5 195</td></tr><tr><td>3</td><td>8 440</td><td>3 380</td><td>4 448</td><td>5 299</td></tr><tr><td>4</td><td>8 580</td><td>3 513</td><td>4 616</td><td>5 403</td></tr><tr><td>5</td><td>8 740</td><td>3 637</td><td>4 784</td><td>5 520</td></tr><tr><td>6</td><td>8 880</td><td>3 770</td><td>4 952</td><td>5 624</td></tr><tr><td>7</td><td>9 020</td><td>3 903</td><td>5 120</td><td>5 728</td></tr><tr><td>8</td><td>9 180</td><td>4 045</td><td>5 316</td><td>5 845</td></tr><tr><td>9</td><td>9 320</td><td>4 188</td><td>5 512</td><td>5 962</td></tr><tr><td>10</td><td>9 480</td><td>4 330</td><td>5 708</td><td>6 079</td></tr></table></td></tr>
<tr><td>Definition</td><td>A satellite-based solution that detects fire events with satellite imagery.</td><td>A historical data-based solution that evaluates the fire damages with a network of field experts</td></tr>
<tr><td>Methodology</td><td>Combination of Modis (20 years of historical data) and Sentinel data (better spatial resolution), to be used according to the client's risk profile and maturity. It is essential to confirm the historical damages between the</td><td>One model available dependent on the tree species, rotation period, and postal code</td></tr>
</table>

	client and the insurer. No historical losses found due to wildfires in the pilot forests or in the region between 2000-2023 from Modis (Burning cost is null)	
Purpose	Cover financial losses decided by the client, often cleaning and replanting costs. No loss assessment processes, fast payouts, worldwide feasibility.	Cover financial losses due to the destruction of assets, in addition to clearance costs, fire extinguishing costs, loss of timber stored in the forest at own risk, and reforestation allowance (German regulation)
Insurance Deductible	Yes, depending on the client's risk appetite. Often around [2%-10%]. For this study: **2%**	No deductible
Insurance Limit	Yes, depending on the surface covered. Often around [10%-30%] to limit the insurance premium to an affordable price. For this study: **15%, 872,000 €** Rate on Line (RoL): **2% (**minimum possible offer)	Could be decided for very large parcels, but not relevant for Germany as the plots are not very large
Value insured	To be given by the client, value based on a price per hectare. Worldwide, varies around [1000-7000€]. For this study: **1938ha at 3000 € / ha**	Theoretical value is 35M€ but the limit would be around 5M€ because of the practical features of the project and small parcel size
Historical data used for pricing	• MODIS MCD64A1 • Sentinel 2 (since 2017)	Historical events based on the postal code of the parcels. Here, very low fire risk detected
Contract duration	Yearly	1-5 years (10% discount), depending on the client
Premium Calculation	Depends on the limit, the deductible, the value insured, and historical events detected by satellite images, the value insured, and historical events detected by satellite images For this study: **17,442€ (9€/ha)**	Depends on the age and tree species, plus risk factors expressed by the postal code (historical fire events, precipitation, expected tree species in the area, general soil and site information) For this study: **[3839€-3455€] [1-year-5-year]**
Comments	Not recommended for wildfire risk in Germany	Recommended

Table 7: Comparison between Wildfire Parametric and Indemnity Solutions

Overall, for this peril, parametric insurance is not recommended since the minimum premium for a parametric insurance policy would often start at 50,000€. In the case of the study region, considering the relatively small surface and the low levels of wildfire risk, the parametric premium is lower than this threshold, and hence not viable.

5 Next steps and Upcoming Work

With the initial completion of the design and development of wildfire and windthrow insurance models for forests in Germany, the project will now focus on the end of Loop 1, and subsequently progress into Loop 2 and Loop 3.

Continuing Loop 1 and in Loop 2, the primary focus will be on refining the insurance models based on feedback and data gathered in the first phase. The windthrow model will be studied in depth, including detailed vulnerability mapping, sensitivity analysis on the proposed indices, and modelling, considering potential adaptation measures. Preliminary results are promising due to low basis risk indicating good potential for insurance applicability. There are however some limitations around data availability and reliability at this stage regarding the losses, parameters and resolution, and new modelling methods and datasets will be explored in the coming months to improve the robustness of the model. It may be relevant to consider the parameters with clustered and more dynamical approaches, as windstorms are complex meteorological features (see e.g., Rantanen et al. 2021, Laurila et al. 2021).

The dataset will be further developed with multiple layers, and tested and replicated in other locations such as Finland in upcoming loops. The next phase will also include extensive surveys to assess levels of interest and key characteristics of forests and owners driving new insurance acceptance probability. These surveys will also help feedback into the existing process and help update the design and development phase where needed.

A detailed investigation on the factors that contributed to storm damages in PIISA pilot countries in the years 2020-2024 could be conducted by PIISA partners as led by FMI. This could include detailed analyses on hazard, exposure, and vulnerability, with a focus on vulnerability factors which could help identify the best adaptation measures. The investigation’s results would contribute to the project’s replicability and would identify which climate change impacts will represent a risk in the near term (2025-2030). Finally, Loop 3 will involve surveys and workshops to assess the potential for the adoption of a new forest insurance scheme in the Boreal region, and the models will be replicated and tested in other locations.

The final outputs of this project would therefore include updated insurance model designs for the pilot location, which will then be tested and potentially replicated in other European locations such as Finland. The results of this replication exercise will also be provided. Several surveys and workshops to increase awareness as well as receive feedback into the work will be conducted, and finally an updated report will be published, outlining the final results of the pilot project, and all its stages.

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