PIISA

Piloting Innovative Insurance Solutions for Adaptation

D2.3 Climate services on insurance options and adaptation alternatives for citizens

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Summary

Deliverable D2.3 presents the climate services developed within Work Package 2 of the PIISA Project. The objective of these services is to support improved understanding, assessment and management of climate-related risks, with relevance for the insurance sector and climate adaptation planning.

The climate services were developed through a co-design process involving project partners, sectoral experts and stakeholders from the insurance community. This process allowed the identification of key information needs and ensured that the resulting products respond to practical decision-making contexts.

Across these pilots, several climate indices and data products were developed to characterise hazard severity and potential impacts. These indices function as impact precursor data, providing quantitative indicators that can support risk modelling, climate risk assessments and the potential design of innovative insurance solutions, including index-based approaches.

To enhance accessibility and long-term usability, several of the indices developed within the project have been integrated into the Risk Data Hub, ensuring that the datasets are openly available and harmonised according to European data standards.

Overall, D2.3 documents the methodological approaches, datasets and applications underlying the climate services developed in PIISA, illustrating how climate data can be translated into actionable information that supports climate resilience and innovation in climate risk management.

Keywords

Climate Services, Climate risk; Insurance; Risk assessment; Pilots; Co-creation; Co-development; Climate adaptation.

Abbreviations and acronyms

Acronym	Description
WP	Work Package
API	Application Programming Interface
BSC	Barcelona Supercomputing Center
CDI	Climate Dryness Index
CMCC	Euro-Mediterranean Center on Climate Change
DVF	Demandes de Valeurs Foncières
EEA	European Environment Agency
ERA5	Fifth generation ECMWF reanalysis dataset
ESG	Environmental, Social and Governance
FMI	Finnish Meteorological Institute
GDD	Growing Degree Days
HCLIM	HARMONIE-Climate regional climate model
JRC	Joint Research Centre
NbS	Nature-based Solutions
SFO	Sustainable Finance Observatory
SHI	Standardized Heatwave Index
SPI	Standardized Precipitation Index
SWI	Standardized Windstorm Index
WPEI	Wind Power Exposure Index

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Introduction

Deliverable 2.3 presents the climate services developed within the PIISA project to support innovative insurance solutions and adaptation alternatives for citizens and local stakeholders. The objective of this deliverable is to document the design, development, testing and potential operationalisation of pilot climate services that translate climate data and risk information into decision-relevant tools for the insurance sector and for adaptation planning.

Within WP2, Task 2.3 builds directly on the foundations established in Task 2.1 and Task 2.2. Deliverable 2.1 provides the structured inventory and assessment of hazard, impact and loss datasets relevant for insurance and adaptation purposes, while Deliverable 2.2 defines the methodological framework for risk analysis, including the integration of hazard, exposure and vulnerability components. D2.3 operationalises these elements by developing concrete climate services tailored to the needs of the five PIISA pilots (Green Roofs, Soil Stability, Agriculture, Forest and Wildfire).

The role of Task 2.3 within WP2 is therefore implementation-oriented: it translates datasets, indices and risk concepts into user-oriented products and decision-support tools. At the same time, it acts as a bridge to WP3, where the feasibility, insurability and business potential of the proposed solutions are assessed. The climate services described in this deliverable are not stand-alone scientific products; rather, they are embedded within broader insurance innovation pathways and adaptation strategies.

A key guiding principle of PIISA is co-design. The climate services presented here have been developed through iterative engagement with insurers, public authorities, technical experts and end-users. Co-design has ensured that the services respond to real decision-making contexts, address specific risk management questions, and meet usability and transparency requirements. In the insurance domain in particular, clarity in index definition, robustness of data sources and traceability of methods are essential to build trust and enable operational uptake.

Overall, D2.3 demonstrates how climate data, impact information and tailored indices can be transformed into actionable climate services that support risk-informed adaptation choices and innovative insurance mechanisms for citizens.

1 Climate Services developed for the pilots

The climate services developed within PIISA are designed to support risk-informed decision-making across multiple sectors exposed to climate-related hazards. Each pilot addresses a specific risk context: urban heat and floods, soil shrinkage, agricultural drought, forest windthrow risks and wildfires, and translates climate information into tailored tools for adaptation planning and insurance design.

Although the thematic focus differs across pilots, all services share common methodological building blocks: (i) the use of robust hazard datasets identified in D2.1, (ii) the development or refinement of climate and risk indices, (iii) the integration of impact and vulnerability information where relevant, and (iv) continuous interaction with stakeholders through a structured co-design process.

The following sections describe, for each pilot, the scope of the climate service, the co-development approach, the data sources and indices used, the delivery formats and visualisation strategies, and the pathways towards operationalisation and commercialisation. Together, these case studies illustrate how climate services can bridge scientific knowledge and practical insurance solutions for citizens.

Each climate service described in this deliverable follows a common structure, designed to ensure consistency and comparability across the different pilot applications. The table below summarises the main sections and guiding aspects considered in each climate service description.

Table 1: template for climate services description

Title of the climate service
Climate service overview • *Target end-users and stakeholders (citizens, insurers, public authorities, etc.)* • *Climate risks addressed* • *Geographic scope* • *Decision-making that the service supports* • …
Co-design and co-development process • *Description of the co-design approach adopted in PIISA* • *Stakeholder engagement methods (workshops, interviews, iterative feedback loops, etc.)* • *How user needs were translated into service requirements*

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Data sources and indices used

- *Refer to D2.1 for dataset used (mention D2.1 section where data are mentioned)*
- *Describe indices/data developed during PIISA*
    - *Data sources used (observations, reanalysis, forecasts, projections)*
    - *Methods for index development*
    - *Temporal, spatial resolution and update frequency*

Delivery and visualisation of the climate service

- *Delivery channels (web platform, maps, dashboards, reports, alerts, APIs, etc.)*
- *Visualisation approaches*
- *Timing and frequency of delivery*
- *Feedback from users on usability (if available)*

Pathways to operationalisation and commercialisation

- *Potential users after the project*
- *Operational requirements (data availability, maintenance, responsibilities)*
- *Business model or sustainability pathway (commercial, public service, hybrid)*
- *Governance aspects*
- *Key barriers and enablers for continuation*

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1.1 Climate Services for the *Green Roofs* pilot

Website - Innovative insurance solutions: green roofs The green roofs pilot explores the role of nature-based solutions in reducing climate-related risks in urban environments. Green roofs can help mitigate the impacts of extreme rainfall and urban flooding, while also contributing to broader adaptation strategies. The climate service developed in this pilot can support the design, evaluation and potential integration of such measures into insurance and risk management frameworks.
Climate service overview The website http://greenroofinsurance.com/ (preview in Figure 1) is an awareness tool for insurers, designed to improve understanding of extreme rainfall risks and the damage-reducing role of nature-based solutions, especially green roofs. It provides information on rainfall-related damage trends, the benefits of green roofs, and practical steps insurers can take to promote nature-based solutions. The website is primarily targeted at European insurers and insurance associations, while also being relevant for other stakeholders involved in urban climate adaptation, including other financial institutions, municipalities, public authorities and the construction sector. The website addresses the increasing risk of damage to homes caused by extreme rainfall, particularly in urban areas where high levels of impervious surfaces and dense development amplify flooding impacts. Its geographic scope is Europe-wide, with illustrative examples and data from multiple European countries and additional detail for the Netherlands. The platform supports decision-making by helping insurers understand trends in rainfall-related losses, explore the role of nature-based solutions and especially green roofs, and identify practical actions, such as “build back better” approaches, premium incentives, and public–private partnerships to stimulate preventive measures and reduce future claims. Co-design and co-development process The platform was developed based on lessons learned from the PIISA case study on green roofs. This study included interviews with European insurers described in the report on enablers and barriers of nature-based solutions (Kroes & Klok, 2026). Insights from these discussions informed the platform's content. This stakeholder input was translated into a website that responds to insurers’ information needs by combining (i) evidence on the increasing impacts of extreme rainfall and associated damage trends, (ii) clear explanations of prevention and nature-based adaptation measures with a focus on green roofs, and (iii) practical recommendations on how insurers can stimulate uptake. These recommendations include offering premium incentives, raising awareness of subsidies, strengthening public–private partnerships, adapting insurance products to support nature-based measures, and applying “build back better” approaches after damage events.

Data sources and indices used

The website does not directly rely on or reproduce datasets described in Deliverable D2.1, and no dedicated PIISA dataset is embedded on the website. Instead, the platform presents statistics and indicators derived from publicly available sources and research literature. These include reported insured and economic losses from extreme rainfall events in Europe (e.g. aggregate European loss figures, national insurance association data for the Netherlands), documented case studies of major rainfall events across European cities, and projections from published climate impact studies indicating increasing frequency and intensity of heavy precipitation. The website also refers to map-based tools such as the Dutch Climate Impact Atlas and municipal subsidy maps to illustrate spatial patterns of flood exposure and green roof potential. The data presented are primarily based on historical observations of insured losses, documented extreme events, and published climate projections; no new indices were developed within the framework of the website itself.

Delivery and visualisation of the climate service

The website is developed by Climate Adaptation Services, following the insurers' expressed needs to increase awareness of climate risks and adaptation options. Content reflects the most recent information available at the time of publication (including loss figures up to 2024/2025) and is updated when new evidence becomes available. A draft version of the website was reviewed by a user group of insurers, who provided feedback on usability and relevance. Users appreciated the clear design, practical examples and the inclusion of maps. It is intended that the website will be disseminated through established networks, such as the Knowledge Portal Climate Adaptation (klimaatadaptatienederland.nl) and the Dutch Association of Insurers.

Pathways to operationalisation and commercialisation

After the PIISA project, the website can continue to serve insurers and insurance associations across Europe, as well as related stakeholders such as mortgage lenders and public authorities involved in climate-resilient housing. The website has limited operational requirements, as it functions as a curated knowledge and awareness tool rather than a real-time data service; continuity mainly depends on periodic content updates and maintenance of links and references. Climate Adaptation Services will maintain the platform under a dedicated domain name for at least ten years, ensuring long-term accessibility. The sustainability pathway is best described as a hybrid public-service model: the platform remains openly accessible Key enablers include its low maintenance burden, relevance for insurers, and strong dissemination channels, while barriers relate to maintaining a clear value proposition, keeping the scope focused, and securing capacity for updates beyond the project lifetime.

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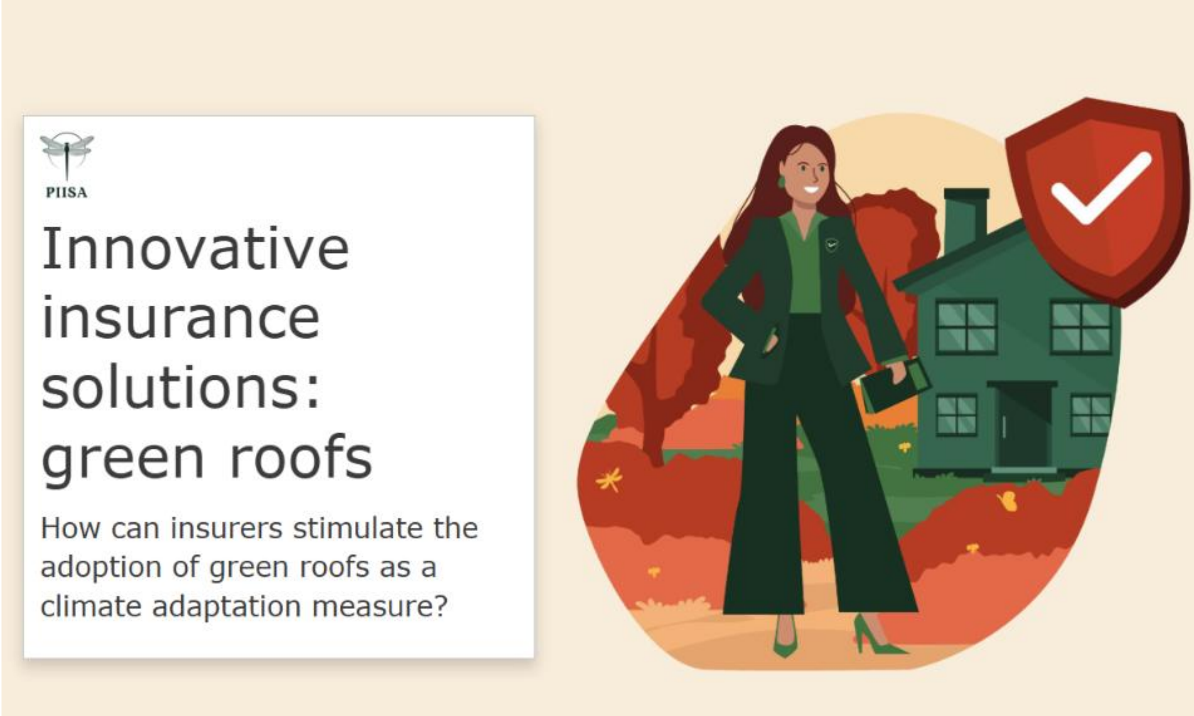

Figure 1: Preview of the innovative insurance solutions tool. Click here to access the tool https://www.greenroofinsurance.com/

1.2 Climate Services for the *Soil Stability* pilot

Climate service for soil stability and clay shrink–swell risk (CSS)

The soil stability pilot focuses on the risk of property damage caused by clay shrink–swell (CSS) processes. Clay soils are highly sensitive to changes in moisture content, expanding when wet and shrinking when dry. These dynamics can lead to ground movement and structural damage to buildings. Climate change is expected to increase the frequency of conditions that trigger CSS events, such as droughts, heatwaves and intense rainfall, thereby increasing the associated risks.

Climate service overview

A key output of the pilot was the development of the Clay Shrink Swell Building Damage Assessor (CSSBDA, preview in Figure 2) which is a web-based tool to communicate to homeowners various information about the financial (and other) risks they face from inadequate insurance cover for property damage caused by clay shrink swell (CSS) events.

Therefore, the climate risk addressed by the pilot is property damage caused by CSS events. Clay soil consistency can easily change depending on the soil's water content. When it rains, clay soils absorb water and dilate just like a sponge. When the water contained in the clay evaporates, then the clay soil shrinks. The drying out of the soil can create both horizontal cracks on the surface and vertical hydromechanical settlement under the weight of the structures (Assemblée Nationale, 2023). Simply put, a CSS event can occur when a drought is followed by heavy rain, causing soil to move and change shape significantly in a short period of time. The increasing likelihood of a CSS event occurring is related to climate change and more specifically to the increasing likelihood of relevant weather events such as droughts, heatwaves and rainfall that can potentially trigger a CSS event.

The CSSBDA was developed and pilot tested in the City of Lyon in France. After addressing user feedback at this stage, the CSSBDA was replicated at French national level. At the same time as this replication at French national level, further research was undertaken to analyse the utility of developing an equivalent web-based tool in other countries and geographic regions in the EU (Finland, Germany, Italy, Luxembourg and Spain).

The principal objective for the CSSBDA is to educate homeowners about their financial risks associated with inadequate insurance cover for property damage caused by CSS events. the CSSBDA is focussed on raising homeowner awareness about a particular insurance issue, with the hope that increased homeowner awareness will leverage pressure on the insurance industry to address the issue (e.g. through requesting specific clauses in insurance contracts).

Co-design and co-development process

Work commenced with background research on the CSS phenomenon and the insurance position in France and a review of public data sources which could be used in the CSSBDA. This research enabled articulation of various aspects of the user journey/interface which should be embedded in the CSSBDA to effectively communicate to the intended audience of homeowners and development of contracting information used to instruct a third-party web developer to build the online version of the CSSBDA. The online version of the CSSBDA was then pilot tested in the City of Lyon in France during the period from March to August 2025. Lessons learnt from pilot testing in the City of Lyon which were then integrated into our planning and work activities for replicating the CSSBDA at French national level. The final stage of the pilot consisted of two primary modes of activity: (a) replication of the CSSBDA at national level in France and associated communication activities to publicise the CSSBDA among relevant audience constituencies; and (b) researching the CSS risk level and insurance framework for other countries and geographic regions to analyse whether developing an analogous tool to the CSSBDA might have utility in these other countries or geographic regions.

Data sources and indices used

The CSSBDA does not directly rely on or reproduce datasets described in Deliverable 2.1.The CSSBDA uses data contained within the ERRIAL tool to enable the CSSBDA to show the level of CSS risk according to geographic location of the homeowner's property. The ERRIAL tool geolocates CSS risks and distinguishes between three levels of risk: Low, Medium, and High.
The CSSBDA also uses data from Land Data Explorer (Explorateur de données foncières[1]) (Ministère de la Transition écologique, Undated) which is a public database that lists property sales and allowed us to estimate a median price for properties in the cadastre sector (see below). This database is based on Government Property Value Request Files (les fichiers de Demandes de Valeurs Foncières du Gouvernement) (DVF).
To assess the CSS phenomenon, a compound index called the Climate Dryness Index (CDI) was developed, which is designed to analyse the combined effect of drought and heatwaves on soil stability risk. The CDI is composed of two standardised single-hazard indices: the Standardised Precipitation Index (SPI) and the Standardised Heatwave Index (SHI), describing precipitation (and lack of precipitation) and high temperatures respectively. SPI is a widely used precipitation-based index (McKee et al., 1993). to describe drought events and their time scale, probability and intensity. SPI can be aggregated at different month scales, enabling flexibility in assessing precipitation patterns over different periods: for instance, a 3-month SPI (SPI3) assesses precipitation anomalies over 3-month accumulation periods. SHI is a novel index developed by Amigo and derived as a modification of an existing heatwave index developed by Russo et al. (2014), widely adopted for monitoring heatwaves. Further details about the index can be found in D3.5 and D3.6.

The two components of CDI have been computed using long-term climate projections of total precipitation and maximum temperature from the Coupled Model Intercomparison Project Phase 6 (CMIP6) (Eyring et al., 2016). For our analysis we selected the two scenarios ssp370 and ssp585, which show the worst conditions in terms of GHG emissions and global warming. Before using this data to compute the indices, a processing step to enhance the reliability of climate projections is performed. This involves applying an innovative bias correction and downscaling technique to correct systematic distributional biases and refine the

[1] https://explore.data.gouv.fr/fr/immobilier?onglet=carte&filtre=tous

spatial resolution of climate model outputs (Trentini et al, 2025). This enables to increase the resolution of the raw data from the original grid (100-250 km) to 0.1° (about 9 km).

Delivery and visualisation of the climate service

The CSSBDA is a website developed by SFO. Following submission of Deliverable 3.5, SFO undertook a procurement process to select a software developer to convert the specification into the online website which forms the CSSBDA.

It communicates to homeowners various information about the financial (and other) risks they face from inadequate insurance cover. This focus on homeowners as the target audience/constituency means that the parameters which shaped the development process for the CSSBDA were different. Homeowners must be assumed to be non-experts in relation to the technical aspects of climate change, CSS, insurance coverage etc. Therefore, communicating to this audience requires transparency, simplicity and clarity. Above all else, the CSSBDA needed to be compelling and easy to use so that homeowners would adopt it.

In addition, the focus on homeowners as the target audience/constituency means that the CSSBDA will not seek to project beyond the base of evidence. For example, the CSSBDA was not seeking to develop a complex actuarial model of the financial risks for homeowners (as might be appropriate for technical users). Rather, the CSSBDA sought to effectively communicate credible and easily understandable information about the financial risks associated with inadequate insurance cover for property damage caused by CSS events in a way which activates homeowners to address the issue with their insurance providers. This means that the methodology sought to keep modelling assumptions to a minimum, and the methodology which sits behind the financial risk metrics draws from existing empirical data (rather than a modelling approach).

The CSSBDA was pilot tested in the City of Lyon in France which allowed for feedback from users and other stakeholders. Altogether, the communication and user experience review confirms that the CSSBDA demonstrated strong potential and was positively received, but several improvements can enhance its clarity and usability. There were no fundamental flaws in the concept or structure, but several refinements were recommended to better serve its target audience. These include improving the homepage messaging to immediately convey the CSSBDA's purpose, enhancing transparency where map data is incomplete, and removing the unnecessary property value estimate to avoid confusion. This feedback was integrated into the CSSBDA prior to it being rolled out at national level.

Pathways to operationalisation and commercialisation

After the PIISA project the CSSBDA can continue to provide information to homeowners about potential risks in relation to inadequate insurance cover in France. The CSSBDA has limited operational requirements, one of which is related to maintenance costs – however it would need to be updated if there are any changes to the insurance framework in France. In addition, it would also need to be updated if there are any changes to the public databases in France from which the CSSBDA draws information. Such changes could also generate additional costs, as the website operates through APIs that may be affected by modifications to servers or to the structure of the databases.

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In addition, research was undertaken to analyse the utility of developing an equivalent web-based tool in other countries and geographic regions in the EU (Finland, Germany, Italy, Luxembourg and Spain). A proposed Risk Alert Briefing will be published which shows that increasing CSS risk combined with inadequate insurance cover are similarly acute in these countries.

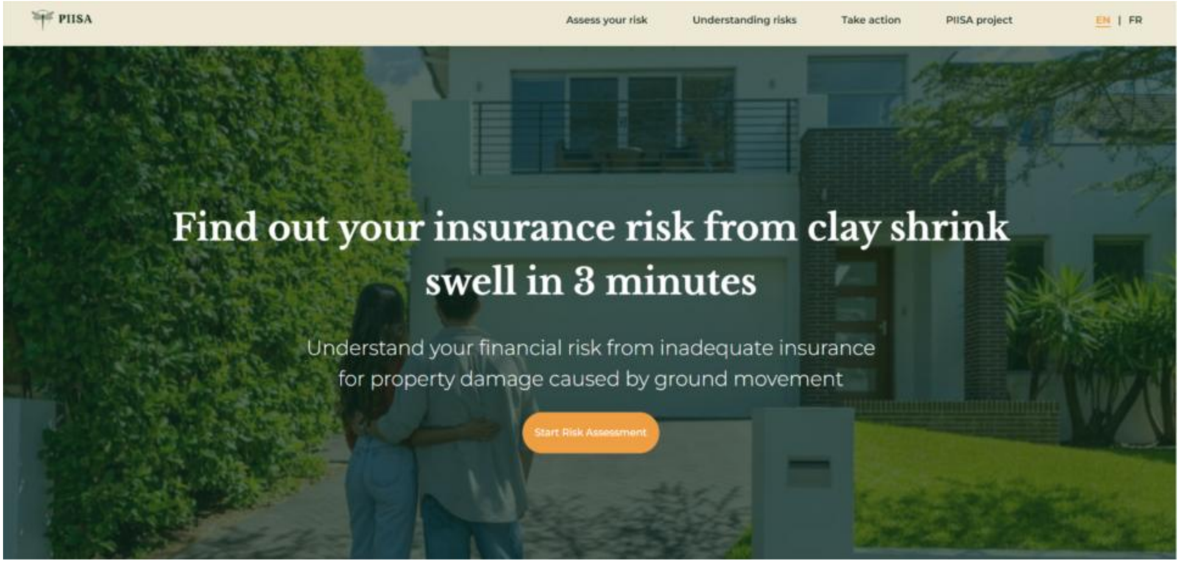

Figure 2: Preview of the Clay Shrink Swell Building Damage Assessor. Click here to access the tool: https://home-risk.eu/en

1.3 Climate Services for the *Agriculture* pilot

Climate Services for the Agriculture pilot

The agriculture pilot focuses on climate risks affecting crop production, including drought, heat stress and extreme events such as hail. These hazards can significantly impact yields and farm income, with implications for the design of insurance solutions. The pilot explores how climate information and indices can support the development of climate services tailored to the needs of farmers, insurers and intermediaries.

Climate service overview

The Agriculture pilot develops climate services to support climate risk management and the development of index-based (parametric) insurance solutions for Mediterranean agriculture, with an initial focus on olive production in Jaén province (Andalucía, southern Spain). Within PIISA, this work is organised around two complementary components: (i) CoDepi (Figure 3), a participatory tool to support the co-design and back-testing of index-based insurance solutions, and (ii) a prototype seasonal-forecast dashboard (Figure 4) that communicates probabilistic seasonal information and associated forecast quality metrics.

Target end-users and stakeholders include insurers and reinsurers exploring parametric agricultural products, farmer organisations and cooperatives (e.g., ASAJA-Jaén) that can act as aggregators or distribution channels, and farm advisors and technicians supporting operational decisions. The climate risks addressed are primarily drought-related production losses linked to rainfall deficits during phenologically sensitive periods; heat stress and cold spells are also recognised as relevant hazards in the local context.

The service supports decision-making by: (a) enabling transparent discussions on index definitions and contract parameters (contract windows, thresholds, payout structures and expected payout frequency) using historical back-testing in CoDepi; (b) providing an ancillary early-warning and preparedness layer via seasonal forecasts, particularly for spring flowering and early fruit set; and (c) informing portfolio monitoring and liquidity planning for insurers and cooperatives through probabilistic seasonal risk monitoring.

The CoDepi framework (Co-designing Parametric Insurance) is described in detail in Deliverable D3.8. Accordingly, this deliverable focuses on the climate component of the Agriculture pilot, namely the prototype seasonal-forecast dashboard and the drought indicator implemented in the dashboard.

Co-design and co-development process

The pilot follows an iterative, stakeholder-centred co-development approach. Engagement was facilitated through ASAJA-Jaén and combined: (i) a farmer survey administered in spring 2025 via ASAJA digital channels (47 complete responses), and (ii) an in-person workshop held in

Jaén on 8 April 2025 with 12 olive farmers and agricultural technicians. Engagement methods included structured questionnaires, interactive polling (Mentimeter), written inputs and facilitated group discussions.

These interactions served to identify critical periods in the agricultural calendar (with a strong focus on March to May) and to elicit locally meaningful climate thresholds associated with damaging years. While several candidate thresholds and potential indices were identified (covering rainfall deficits, heat extremes and frost), the prototype seasonal-forecast dashboard implemented within PIISA operationalises a single drought indicator (described below), in addition to the provision of essential climate variables (ECVs). This scope limitation was chosen to prioritise transparency, reduce complexity for first-time users and ensure robust validation and communication of forecast skill.

Data sources and indices used

The drought-relevant hazard information aligns with the dataset inventory in Deliverable D2.1. In particular, D2.1 (Table 3.1 appendix) includes the Three-Month Dry Accumulation Probability Index (DAP150) for the Iberian Peninsula, defined as the probability that accumulated precipitation over a consecutive three-month period is below 150 mm (coverage 1993-2026; spatial resolution 1 degree; access upon request).

For the seasonal-forecast component, the dashboard uses the ECMWF seasonal prediction system SEAS5.1 (distributed through the Copernicus Climate Change Service). Forecasts are ensemble-based and expressed probabilistically. Precipitation forecasts are bias adjusted following established post-processing approaches (e.g., Leung et al., 1999; Torralba et al., 2017), and hindcasts are used to quantify historical forecast skill over 1993-2016 using the Ranked Probability Skill Score (RPSS). In addition to the indicator described below, the dashboard provides ECV forecast and skill information (e.g., total precipitation and near-surface temperature metrics) to support interpretation and appropriate use of seasonal information.
The threshold-based indicator implemented in the climate dashboard is a drought probability product aligned with the farmer-defined spring rainfall deficit threshold. It is defined as the probability that three-month accumulated precipitation falls below 150 mm for a target season (for example March-April-May):

$$DAP150 = P(P3m < 150 \text{ mm})$$

where P3m is total precipitation accumulated over the three-month window (mm) and P(.) denotes probability. In an ensemble forecast context, this probability is estimated as the fraction of ensemble members for which the event occurs. Although additional thresholds for heat and cold extremes were identified during co-design, they were not implemented as dashboard indicators within the current PIISA prototype.

Historical climate information supporting the co-design and validation activities draws on widely used observation-based and reanalysis products, including CHIRPS precipitation (for precipitation deficits) and ERA5-Land temperature reanalysis (for temperature extremes and contextual analysis of reported damaging years).

Delivery and visualisation of the climate service

The seasonal-forecast component is delivered through a prototype web-based dashboard (Shiny application) hosted on BSC infrastructure. The interface allows users to select the forecast start date and lead time, and visualises results primarily as maps over the Iberian Peninsula. Outputs include: (i) probabilistic seasonal forecasts of ECVs, (ii) forecast quality assessment maps (RPSS) for the same variables and event definitions, and (iii) DAP150 probability maps for the selected three-month season.

Forecast products are updated according to the seasonal forecast release cycle (monthly initialisations). Communicating forecast probabilities together with objective skill diagnostics is an explicit design choice to reduce misinterpretation and to encourage appropriate use as an ancillary climate service (rather than a contractual trigger) alongside index-based insurance.
Feedback collected during the survey and workshop indicates strong interest in financial risk transfer instruments and highlights the importance of simple, transparent indicators and clear communication of uncertainty. Stakeholders also stressed the need to limit basis risk through appropriate spatial aggregation and, where feasible, the integration of local station information into index design and validation workflows.

Pathways to operationalisation and commercialisation

Planned technical developments include multi-system evaluation (combining additional Copernicus seasonal prediction systems alongside ECMWF) to strengthen robustness, and the progressive extension of dashboard indicators as additional event definitions are validated. In terms of commercialisation, the dashboard and the co-design methodology can support insurance partners in developing and communicating parametric products, while the operational insurance offering would be delivered through established market actors and aligned, where relevant, with national agricultural insurance frameworks.

Future development and potential extensions

Climate change is putting growing pressure on food production across Europe, though its impacts differ between semi-arid regions and areas that have traditionally been wetter. As water scarcity increases in southern Europe and rainfed agriculture becomes less reliable in Central and Northern Europe, there is a clear need for indicators that can better capture water-stress risks to crops. To address this, we developed two indicators. The first estimates potential yield loss under rainfed conditions, based on precipitation deficits and expressed through deficits in potential crop evapotranspiration when irrigation is absent. The second, the Standardized Precipitation and Growth Index (SPGI), combines precipitation anomalies with growing season length to describe drought conditions in a way that reflects water availability during the most critical stages of plant growth.
While these indicators are not currently part of the PIISA agricultural parametric insurance framework, they offer a complementary and more process-based view of drought-related production risks. By directly linking precipitation deficits, growing season characteristics, and crop water demand, they provide a practical foundation for assessing climate-driven yield vulnerability. Looking ahead, these indicators could support agricultural pilot applications by informing early warning systems, guiding the development of water-stress-resilient

management strategies, and potentially contributing to future parametric insurance approaches that are more closely aligned with crop growth and yield losses.
The emerging risks linked to water scarcity call for the application of adaptation measures. However, one of the main barriers remain the initial investment. The European Investment Bank estimated that adaptation of agriculture will cost between € 11bn and €17bn per year until 2050. Insurance could play a key role in supporting adaptation actions through incentives integrated in the policies. During the activities of the agriculture pilot, key stakeholders in the sector highlighted the need to incorporate information on the level of adaptation into the insurance policies. Motivated by this request, PIISA performed a preliminary assessment of the basic requirements for adaptation metrics that quantifies the benefits of adaptation measures. Through interviews and surveys, it has been demonstrated that such set of metrics should be aligned with the ESG metrics, quantitative and based on independent trustworthy datasets. Much work still needs to be done to properly define such metrics. Ongoing projects carried out by PIISA partners are already pushing forward the State-of-the-Art in this respect, but follow-up activities are indeed essential to demonstrate the benefit of such set of metrics for the entire value chain.

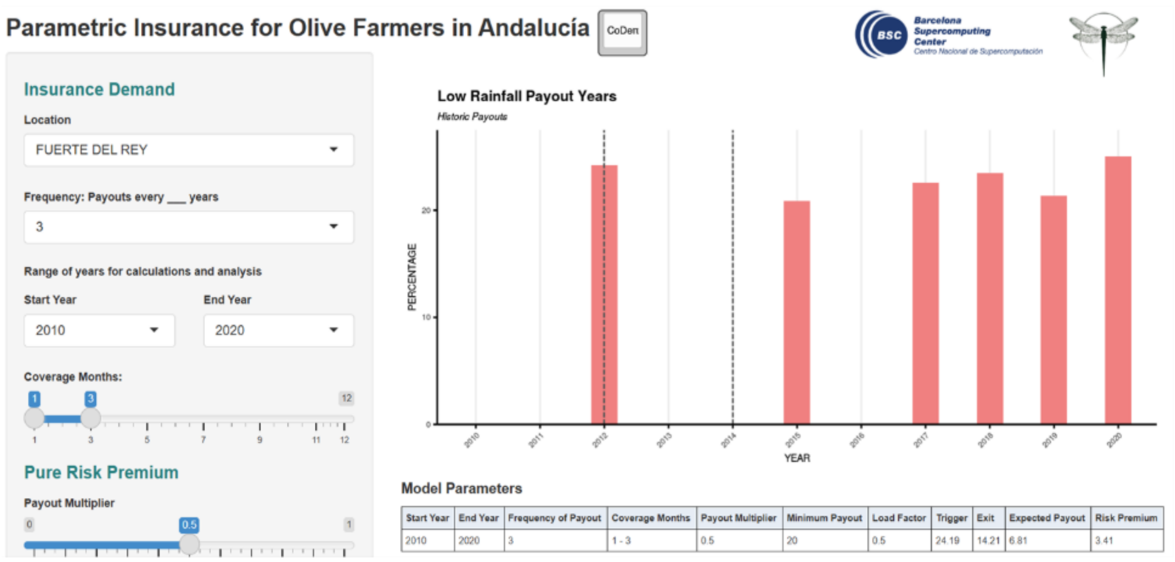

Figure 3: preview of the CoDePi tool for agricultural insurance. To access, click this link https://earth.bsc.es/shiny/ss_PIISA/ and use these credentials: **username:** piisa, **password:** ibibsc

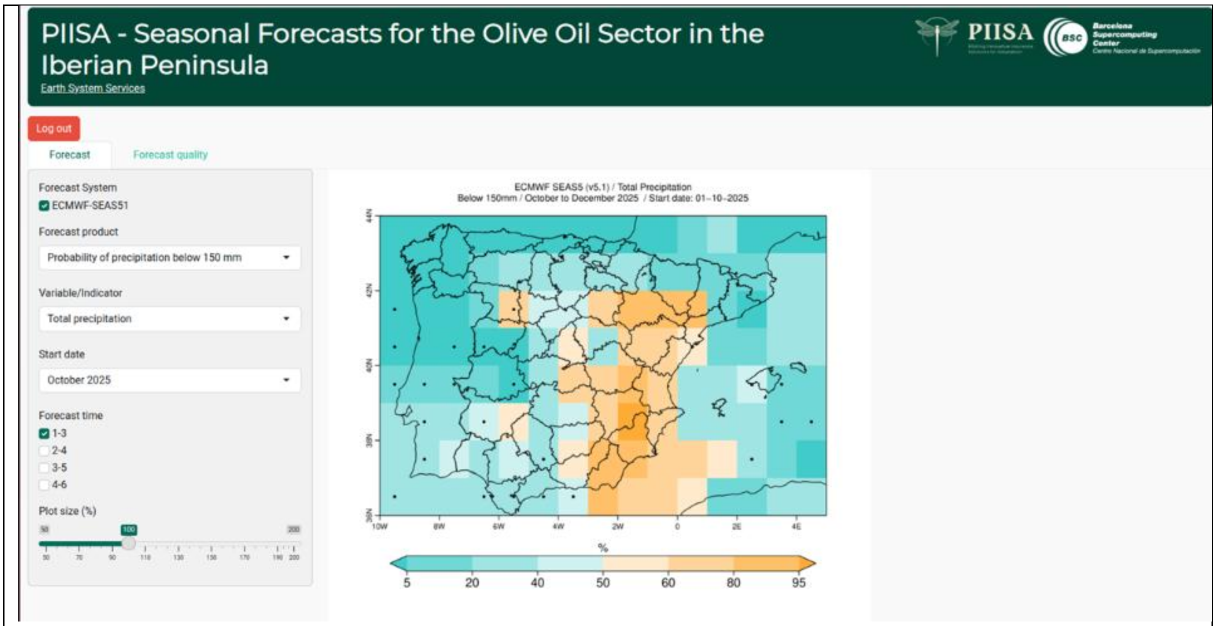

Figure 4: Shiny app for seasonal forecasts

1.4 Climate Services for the *Forest-windthrow* pilot

Overview of climate services for the Windthrow Pilot

The forest-windthrow pilot addresses climate risks affecting forest ecosystems, particularly windstorms and other disturbance events that can cause significant economic losses. Forest damage is influenced by both hazard intensity and forest vulnerability, making risk assessment complex. The climate services and indices developed in PIISA can support risk assessment and the development of insurance solutions for the forestry sector.

Climate service overview

Various climate services were explored in this pilot, with various potential uses depending on end user and timeline. For instance, vulnerability maps were developed, integrating local information to assess the susceptibility of wind disturbance on forests, with a model trained in France and tested and evaluated in Germany and Ireland, with good alignment with ground truth data and scalable methodologies. It can help foresters identify high-exposure areas before storms to modify rotation lengths, limit clearcuts, and orient stand edges. A wind power exposure index was also developed, based on a combination of hourly wind speed, wind direction, and storm duration. Combined with a vulnerability curve, the expected damage within a forest after a storm can be extracted using it. The Standardized Windstorm Index developed by Amigo can also be used as a seasonal forecast to plan for salvage capacity for potential blowdowns or to delay or advance thinning.

The primary end-users for this pilot are forest owners and managers and insurance and re-insurance companies. Other stakeholders include public authorities responsible for forest risk management and climate adaptation, as well as climate-service providers supporting risk assessment.

The main focus is on wind-related risks to forests, with a focus on windthrow and storm damage.

The pilot started with a focus on selected forest areas in Germany, with methodological testing and calibration also performed across additional European regions including Denmark, Ireland, and Scotland to assess replicability and transferability.

The climate services support insurance pricing and product design, risk differentiation across forest stands, and strategic forest management decisions. It enables insurers and forest managers to assess vulnerability, relative wind risk, identify high-exposure areas, and evaluate insurability under different risk thresholds.

Co-design and co-development process

The pilot followed PIISA's iterative, loop-based co-design approach, combining technical development with continuous stakeholder feedback. Climate services were developed in parallel with insurance design to ensure usability and relevance.

Stakeholder engagement included monthly technical meetings with project partners and dedicated stakeholder workshops when needed with real-time feedback and interaction with relevant stakeholders.

Funded by the European Union

User needs translated into requirements for scalable indices, clear vulnerability metrics, and the ability to test historical storm events against model outputs.

Data sources and indices used

Core datasets and indices are described in detail in the PIISA Deliverable 2.1.
Data sources include historical storm records and forest damage data, forest inventory and stand-level characteristics (species, age, structure), and ERA5-Land reanalysis data
The wind power exposure index (WPEI) was developed as a combination of hourly wind speed, wind direction, and storm duration, and calibrated against historical storm damage where available. It is based on ERA5-Land data from Copernicus and is developed using aggregated hourly data at 11km resolution, available from 1950-2025.

Delivery and visualisation of the climate service

The service outputs were delivered through technical reports (outlined in detail in PIISA Deliverable 3.13), and the dataset and index developed was shared through the EU Risk Data Hub.
For insurance utilisation, on-demand underwriting and portfolio assessments can be conducted to provide pricing estimates based on the localized risk and insurance needs.

Pathways to operationalisation and commercialisation

Potential uses after the project include insurers, reinsurers, forest owners, managers, and cooperatives, public authorities, and climate-service providers
Continued access to ERA5-Land data is needed for operational continuity, and forest inventory datasets and historical storm damage data is needed for regional calibration in new regions.
A hybrid business model can be envisaged, where core hazard indices function as climate services and are combined with insurer-specific pricing and product strategies.
Key enablers include open-access climate data, and forest manager and insurer engagement. Barriers include data gaps in regions lacking detailed forest damage data and the need for regional calibration.

Future development and potential extensions

PIISA also presented climate indices with broader climate service scope that were integrated into the Risk Data Hub (see D2.1). These were not directly implemented in the pilot but may have future relevance for the sector.

Convective storms can damage forests through lightning and strong wind gusts. We developed indices as proxies for thunder days and severe thunder days, which were applied to ERA5 reanalysis data from Copernicus for Europe (1940–2024) and high-resolution HARMONIE-Climate regional climate model data for Fennoscandia (2041–2060 and 2081–2100, RCP4.5 and RCP8.5). This enables assessment of past and projected changes in thunderstorm-related hazards and provides insights for many sectors assessing their adaptation needs.

In addition, the Standardized Windstorm Index (SWI) was developed to provide a robust and comparable metric for intense windstorms. The index is based on spatially aggregated near-surface wind speeds exceeding location-specific high percentiles, enabling extreme wind events to be detected and ranked consistently across regions and time periods. By standardizing wind intensity relative to local climatology, the SWI enables comparison between historical events and projected future changes. The index was designed to be applicable across different datasets, including reanalysis and seasonal forecast products, thereby supporting both retrospective impact analysis and forward-looking risk assessment. Although not directly implemented in the pilot workflows, the SWI offers strong potential for future integration into underwriting and portfolio risk monitoring.

1.5 Climate Services for the *Wildfire* pilot

Overview of the climate services for the Wildfire Pilot

Climate service overview

Climate services in this pilot primarily include fire risk and burn probability maps developed for the study region based on fire simulations, taking into account historical burned area data, land cover, fuel type, topography, and forest data, which can help increase awareness of the fire risk levels and need for adaptation measures in the region. A stochastic wildfire catalogues has been developed to inform future decision-making, and climate data from the Fire Weather Index (FWI) can also be helpful as a complementary source.
Primary users include public authorities (Portugal's Rural Fire Management Agency [AGIF], regional and municipal authorities), forest owner associations and cooperatives, building owners and general public, insurers, and climate-service providers. Policymakers involved in wildfire adaptation and land-use planning are key stakeholders as well.
Wildfire risk is the key risk addressed, including fire occurrence, spread, intensity, and burned area, with explicit consideration of climate-driven fire weather and adaptation measures.
The pilot focused on the Caramulo and Ribeira da Mega region in Central Portugal, with a view toward potential applicability in Mediterranean and fire-prone regions.
These climate services support wildfire risk assessment, insurance design and pricing, and public-sector decision-making on risk reduction investments such as adaptation measures.

Co-design and co-development process

The Portugal pilot followed PIISA's loop-based co-design methodology, integrating climate modelling, insurance design, and adaptation planning through continuous engagement with stakeholders.
Stakeholder engagements included monthly technical work sessions with all PIISA project partners and AGIF to receive regular feedback to help refine scenarios and outputs. Other engagement methods such as questionnaires, workshops, and webinars were planned on a need basis. Stakeholder inputs and needs shaped the selection of adaptation scenarios, and model outputs.

Data sources and indices used

Datasets and climate indices are described in detail in PIISA Deliverable 2.1.
Data sources used include the Fire Weather Index (FWI), MODIS burned area products for historical wildfire reconstruction, land cover, fuel type, topography, and forest data, and risk maps provided by Portuguese authorities.
Annual burn probability maps, fire size distributions, and wildfire catalogues were developed for the study area.
Fire simulations were conducted using two different fire spread models (MTT and WISE), calibrated using historical fire events and fire regimes.

Delivery and visualisation of the climate service
Detailed information surrounding the development of this work has been documented in PIISA deliverable 3.13, and the stochastic wildfire catalogues have also been shared to the EU Risk Data Hub for broader access and dissemination to the maps directly The data is all available in a visual format, as risk maps, annual burn probability maps, fire footprints, and wildfire catalogues.
Pathways to operationalisation and commercialisation
Public authorities, forest owner cooperatives and associations, insurers, general public, and climate-service providers in Portugal and fire-risk prone areas would be the primary potential users following the PIISA project. Sustained access to fire weather data, satellite observations (e.g. MODIS or similar) would be needed, with localised data required for new regions to re-calibrate the fire models when trying to replicate the work A primarily public or hybrid model is envisaged, with climate services supporting public planning and awareness raising exercises, as well as enabling insurance solutions linked to adaptation policies. Strong alignment with public sector institutions and adaptation policy frameworks is essential. WISE fire spread model used in calculation of burn probabilities will be implemented to Climate Change Adaptation Digital Twin of the Destination Earth which is a flagship initiative of the European Commission to develop a highly-accurate digital model of the Earth.

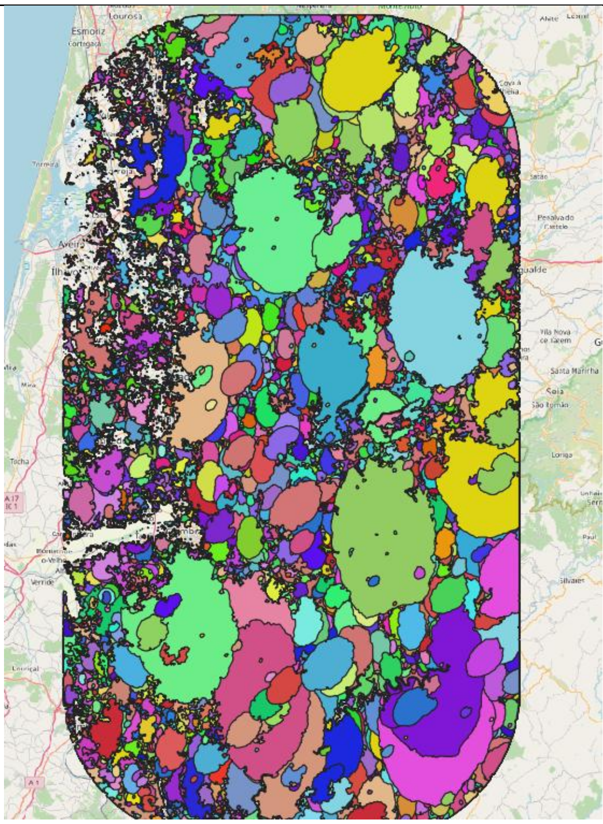

Figure 5: visualization of the wildfire catalogue

Conclusion

The climate services developed within the PIISA Project demonstrate the potential of climate data and hazard indicators to support improved climate risk assessment and the development of innovative insurance solutions.

Through the pilot activities, the project has produced a set of climate indices and products addressing different climate hazards and sectors, including agriculture, forestry and wildfires. These indicators provide structured and harmonised information on hazard severity and potential impacts, enabling a better understanding of climate risks and supporting the development of data-driven climate services.

Overall, the results presented in D2.3 illustrate how climate services can act as a bridge between climate science, risk assessment and financial risk management. By improving the availability and usability of climate risk information, these services can support more informed decision-making and contribute to strengthening climate resilience across Europe.

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