PIISA

Piloting Innovative Insurance
Solutions for Adaptation

D2.1 Catalogues of collected empirical and generated original data on climate related risks, damage, and losses

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List of contents

List of figures

List of tables

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Abbreviations and acronyms

Acronym	Description
AR6	6th Assessment Report (coordinated by IPCC)
C3S	Copernicus Climate Change Service
EEA	European Environmental Agency
IPCC	Intergovernmental Panel on Climate Change
JRC	(EU) Joint Research Centre
NUTS	Nomenclature of Territorial Units for Statistics (Eurostat)
RDH	Risk Data Hub
RDLS33	Risk Data Library Standard
WP	Work Package

Summary

This deliverable presents the identification, organisation and documentation of climate change impact data relevant for the objectives of the PIISA project. The work carried out under Task 2.1 aims to strengthen the data foundations required to support climate risk assessment and the development of climate services for the insurance sector.

Insurance-based climate risk management requires integration of several types of information, including hazard observations, vulnerability data and, critically, damage or impact data. However, the availability and accessibility of climate impact datasets remain uneven across Europe, and information on economic losses or damage records is often fragmented, inconsistent or difficult to access.

In this context, D2.1 provides a structured inventory of climate change impact datasets and related data portals at the European level, with particular attention to datasets that can support insurance decision-making and climate risk analysis. While the catalogue does not aim to be exhaustive, it highlights key datasets and platforms that are widely used or particularly relevant for the sectors and hazards addressed in PIISA.

A central component of the deliverable is the development of an online catalogue that organises this information in a structured and searchable format, allowing users to explore datasets, understand their characteristics and identify potential sources of impact data for climate risk analysis.

In addition to the inventory of existing datasets, the deliverable documents the integration of selected climate indices developed within PIISA into the Joint Research Centre (JRC) Risk Data Hub. These indices represent climate hazard indicators and impact precursor datasets that can support risk assessment and the development of climate-informed insurance solutions. While D2.1 documents their integration into the broader data landscape, the detailed technical description of these indices and their role within pilot climate services is provided in Deliverable D2.3.

Overall, D2.1 contributes to improving transparency and accessibility of climate risk data, supporting the development of innovative climate services and insurance solutions aimed at strengthening climate resilience across sectors.

1 Introduction

Deliverable D2.1 provides an overview and structured inventory of climate change impact data and related datasets relevant to the objectives of the PIISA project. The deliverable has a dual purpose: on the one hand, it is a written report describing the scope, selection criteria and organisation of the data collected under Task 2.1. On the other hand, it is linked to an online catalogue that makes this information accessible in a structured and searchable format.

Within the context of Work Package 2 and Task 2.1, D2.1 supports the identification, collection and organisation of climate change impact data that can inform the development of new climate data services within PIISA. These data are used either as standalone inputs for WP2 services or as supporting elements for the pilot applications developed in WP3. As such, the deliverable plays an important role in ensuring that climate services developed in PIISA are grounded in robust, transparent and well-documented data sources.

The deliverable offers two main strands of collected and internally generated climate change related impact data and impact precursor data. Firstly, it presents a capita selecta of impact data sets from different EU countries, which as much as possible represent damage or damage categorisation rather than hazard levels or ratings. Secondly, it summarises how new climate services, mostly various severity indices, are integrated into the EU's Joint Research Centre's (JRC) Risk Data Hub. A selection of these indices, which most clearly function as impact precursor data, is also included in the capita selecta mentioned above.

The search for impacts data was undertaken since insurance companies, as well as adaptation planning organisations, need damage data in conjunction with hazard observation data, and vulnerability data to assess (economic) risks for different levels of hazards and vulnerability at meaningful spatial scales. The availability and accessibility of damage data is however very patchy across Europe (Ceolotto et al 2024; Berninger et al 2026). The capita selecta aims to illustrate that with more (joint) efforts more damage data can be disclosed and replicated elsewhere.

The summary regarding the integration of new data developed in PIISA into the JRC Risk Data Hub is included to clarify the points of departure as well as the data quality and harmonisation requirements, and generally to account for the work done.

It has also been an objective of T2.1 to explore possible links with the European Climate Adaptation Platform Climate-ADAPT, managed by the European Environment Agency (EEA) in cooperation with the European Commission.

Initial discussions were held to assess the possibility of integrating selected climate indices developed within PIISA into the platform. However, as Climate-ADAPT is jointly managed with the European Commission, any additions to the platform need to be carefully aligned with the Commission's strategic guidelines and objectives. This governance structure ensures consistency, coherence and the overall quality of the content presented on the platform. At the present stage, the EEA indicated that they are not in a position to embed new products or datasets directly within the platform. Nevertheless, the Climate-ADAPT team interest in the work carried out in PIISA and openness to exploring potential integration opportunities in the future once alignment on scope and priorities has been clarified.

In the meantime, alternative options for visibility and dissemination of PIISA outputs through Climate-ADAPT were discussed. These include the possibility of updating the project description page to include links to the climate indices once they become available through the JRC Risk Data Hub, as well as the potential promotion of the results through the Climate-ADAPT newsletter at the end of the project. The page for PIISA is already created and can be found here (DRMKC Risk Data Hub) at the end of the list.

2 Conceptual framework and definitions

The Piloting Innovative Insurance Solutions for Adaptation (PIISA) project seeks to develop innovative, context-sensitized insurance products based on an integrated approach that promotes virtuous interaction between risk sharing and risk reduction in adaptation planning and implementation. To ensure consistency across the project's climate services and alignment with international standards—such as the assessments by the IPCC AR6 Working Group II—this section establishes the foundational conceptual framework and key definitions utilised within this deliverable.

2.1 Terminology aligned with PIISA and international standards

The creation of weather and climate-related risks starts from a hazard, but the eventual realised risk depends heavily on the impact pathway and the associated intermediate and societal impacts. Hence, the eventual judgement of overall risk level depends – a priori – just as much on the severity of the hazard as on the extent of exposure (the value at risk) and the vulnerability of the exposed entity. The following definitions align the PIISA project with established international methodologies:

- Hazard: In the context of this deliverable, hazard data refers to measured or forecast weather or climate conditions (such as temperature, precipitation, and wind speed) and their statistical properties. Furthermore, data related to flooding (e.g., discharges, storm surges) and soil properties (e.g., moisture, frozen/unfrozen state) can also be integrated into the description of certain hazards.
- Exposure and Vulnerability: Managing climate change risks effectively requires adaptation through risk prevention, which aims to reduce both exposure and vulnerability. Vulnerability encompasses the characteristics that increase a system's susceptibility to harm. For example, in the context of urban heat stress, the share of people aged 75 and over in a neighbourhood serves as a critical vulnerability metric. Vulnerability, exposure, and insurance coverage metrics are actively integrated into tools like the PIISA Adaptation dashboard for citizens (so far focused on clay shrink swell hazard for home owners).
- Impact: Impacts are the cascading effects propagated by hazardous conditions. These begin in the geophysical sphere (e.g., changes in river discharges, soil moisture, and the degree of frost in the ground) and move to the biophysical environment (e.g., changes in the growth and decay of biomass and ecosystem services). Ultimately, these effects impact the manmade environment (building stock, infrastructure, and agriculture) and human populations (health effects, medical care needs, and cooling/heating demands). It is important to note that different actors view impacts differently: while a climate scientist may view a change in river discharge as an impact, an insurer defines an impact as a change in the probability of exceeding critically damaging water levels or a change in value at risk.
- Damage and Losses: These represent the measurable physical and monetary manifestations of impacts. This classification includes observed physical impacts on production, capital stock, and public health. Additionally, it covers observed and attributed economic impacts, such as reported damage quantified in euros based on visual inspections, remote sensing, insurance claims, or modelled damage derived from hazard severity (e.g., flood depth, wind speed) and the features of the affected area.

2.2 Aspired scope of impact data: observed and projected physical damage or socioeconomic loss

While Deliverable D2.1 encompasses various types of data—including empirical observed datasets, model-derived datasets, and pilot-specific data—it places a particular emphasis on impact data. Given the diversity in understanding of what an "impact" encompasses, the project distinguishes between several levels of impact data, ranging from basic damage proneness (Level 1) to overall macroeconomic impacts (Level 7).

The specific scope adopted in D2.1 focuses on **level 3 impact data and selected datasets**. Within the established framework (see Table 3.1 in §3.1.2), Level 3 data is defined as observed physical impacts on production, capital stock, and public health. Practical examples of this data level include inundation maps showing water depths alongside real estate and land use, or drought index maps detailing deviations in crop-specific yields compared to normal years.

During internal consultations, a consensus was reached among PIISA consortium members that this specific level of impact data is strictly required for many practical adaptation and insurance purposes. While insurance companies naturally possess highly granular economic damage and claim data (Levels 3 and 4) from their customer bases, privacy legislation and competition concerns usually restrict this data from being available to third parties.

Therefore, to fulfill the project's objectives without violating confidentiality, the selected datasets curated in this deliverable focus on verified impact data from acknowledged authorities or expert organisations. To be included, these selected datasets must possess data quality assurance, sufficiently specified metadata (such as area, time period, spatial/temporal resolutions, and associated uncertainties), and be at least partially accessible to third parties, ensuring they can robustly underpin risk analysis and resilience planning across the EU.

2.3 The significance of combinable hazard, impact and vulnerability data

The creation and provision of adaptation aware insurance as well as the planning and implementation of adaptation measures is highly dependent on good availability of and access to hazard, impact and vulnerability data for different parties involved. There is increasing evidence from the literature that better and easily accessible data enable more loss reduction and productivity increases by informing planning, prevention, and protection (Vroege et al 2021, Adkins et al 2021; Dormady et al 2024). By means of value chain analysis (VCA) an assessment can be made about the extent that lacking and poor-quality information may reduce attainable economic value of an information-based insurance or adaptation service (Ebert et al 2024). It is not the purpose of this report, nor of the PIISA project to actually quantify the value of improvements in the availability or accessibility of (impacts) data. It is nevertheless useful to illustrate how VCA can help to inform adaptation planning and insurances about what can be expected to be a justifiable incremental data effort given the extra economic value it is expected to enable.

For public organisations and smaller insurance companies data cost can be an obstacle for planning measures and developing new products. Data cost refers here to a broad range of costs incurred when collecting, processing and using data for analysis of risks and risk reduction effects of measures, including data acquisition, staffing, external expertise, and equipment and services. Just data acquisition cost is not necessarily the largest problem. Instead, the scattering of different types of (impact) data over different owners and holders makes data harder to find and often entails more harmonisation efforts and less optimal quality compromises. It may also increase uncertainty regarding the continuity of the availability of data.

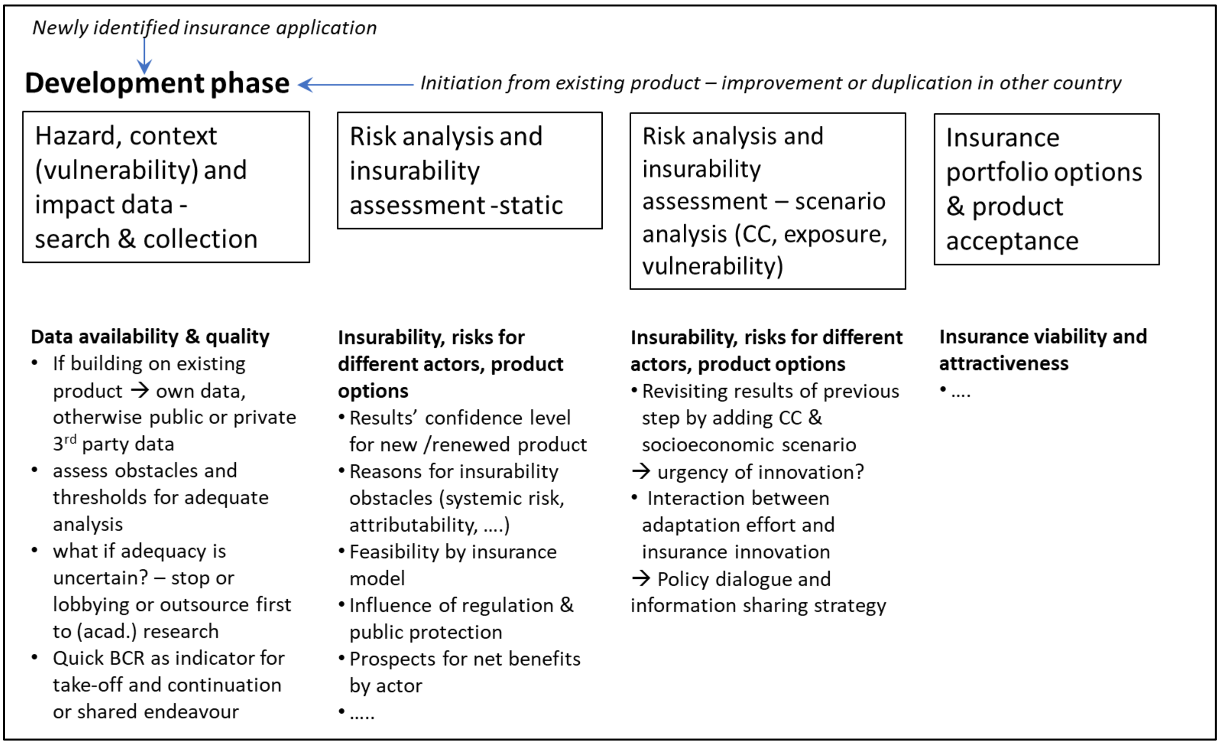
In some cases, high data cost could be largely avoided if sufficient and lasting collaboration between public and private parties can be established, including adequate data sharing agreements and facilities. Limited collaboration, e.g. owing to concerns about competition and privacy protection, can result in data cost (in a broad sense) becoming an obstacle for adaptation and innovation.

For larger insurance companies, the revenue potential of a new product may be orders of magnitudes larger than the data cost in a broad sense, and hence high data cost as such may not be a deterrent. Yet, larger insurance companies have a portfolio of potential innovations from which they should choose the ones with the best expected revenue potential. This means that the opportunity cost of a *protracting* insurance innovation project can be high as the effort for an innovation with significant delay and quality risk would preclude or at least postpone the development of another innovation with less risk.

With the aid of VCA a scan of all factors affecting the cost and duration of the innovation process can be conducted. On the one hand, this can help actors in individual cases to assess the critical factors and alternative solutions for these such that the feasibility and viability of the adaptation measure and/or insurance innovation remain at least reasonable. Such a VCA can be conducted prior to starting the innovation process (to inform the innovation funding decision) and during the innovation process to judge whether continuation and additional cost are justified. On the other hand, VCA can be used to assess adaptation planning and implementation as well as insurance innovation more generally for a country or sector or hazard with the aim to identify obstacles and associated solutions with the aim to speed up adaptation and creation of adaptation aware insurance.

Figure 2.1 provides a summarized impression of the innovation value chain. In different cases and organisations these stages may be organised in a bit different way and partly conducted simultaneously. There may also be feedback loops. For example, returning to stage 1 if problems are identified in stage 3. The aspects to be accounted for in each stage are not exhaustive and provide just as an illustration of the process's complexity. A further explanation of the approach is provided in Appendix 1.

The key point made here is that promotion of good availability and accessibility of free or at least affordable impact data is essential in order to avoid increased or even prohibitively high cost of adaptation planning and insurance innovation and consequent slowdown of reduction of the adaptation gap and the insurance protection gap.



Data availability & quality
- If building on existing product → own data, otherwise public or private 3rd party data
- assess obstacles and thresholds for adequate analysis
- what if adequacy is uncertain? – stop or lobbying or outsource first to (acad.) research
- Quick BCR as indicator for take-off and continuation or shared endeavour

Insurability, risks for different actors, product options
- Results' confidence level for new /renewed product
- Reasons for insurability obstacles (systemic risk, attributability, ….)
- Feasibility by insurance model
- Influence of regulation & public protection
- Prospects for net benefits by actor
- …..

Insurability, risks for different actors, product options
- Revisiting results of previous step by adding CC & socioeconomic scenario

→ urgency of innovation?
- Interaction between adaptation effort and insurance innovation

→ Policy dialogue and information sharing strategy

Insurance viability and attractiveness
- ….

Figure 2.1. A stylized value chain for insurance innovation for climate adaptation

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3 Data collection and selection strategy

3.1 Types of data included

3.1.1 Distinction by origin

The impact data catalogue developed under Task 2.1 covers different types of data sources, reflecting the diversity of information required to support climate risk assessment and climate service development within PIISA. The catalogue includes:

- **empirical observed datasets**, derived from in situ measurements, monitoring networks or observational records. These datasets provide essential information on past and current climate conditions and impacts, and are often used for baseline assessments, validation purposes or the derivation of impact indicators.
- **model-derived datasets**, including outputs from climate models, impact models and reanalysis products. These datasets enable the analysis of future climate-related risks and impacts under different scenarios, and are particularly relevant for forward-looking assessments in insurance and adaptation planning.
- **pilot-specific data**, generated or processed within the PIISA pilots themselves. These datasets may result from tailored analyses, co-designed methodologies or integrations of multiple data sources, and reflect the applied and service-oriented nature of WP2 and WP3 activities.

These different data types may contain hazard-related information, impact-related information, or a combination of both, depending on the variable considered and the stage of the risk pathway they describe. In line with the objectives of Task 2.1, Deliverable D2.1 places particular emphasis on impact data, while recognising that hazard data often constitute a necessary input for their derivation and interpretation. The distinction between hazard and impact data, and the different levels at which impacts can be described, is discussed in the following section.

3.1.2 Distinguishing between hazard and impact data

From the point of view of adaptation and insurance, not only are hazard data important, but also data on the impacts associated with realised hazardous weather and climate conditions. Hazardous conditions propagate effects and hence impacts, first in the geophysical sphere, e.g. through changes in river discharges and in soil moisture, degree of frost in the ground, subsequently in the biophysical environment, e.g. through changes in growth and decay of biomass and in ecosystem services in general. Both types of effects in the natural environment eventually impact on the manmade environment (building stock, infrastructure, agriculture) and on people themselves (health effects; medical care needs; cooling and heating needs).

Even though the creation of weather and climate related risks starts with a hazard the eventual risk depends on the impact pathway and the associated intermediate and eventual societal impacts. From a climate service development perspective, it may be more straightforward to elaborate from hazard to initial and possibly follow-up impacts. Conversely, for insurance developers as well as clients, and for sectoral or regional adaptation planners the eventual (reducible) compound impact on property value, liveability or production counts. From these descriptions can be inferred that different experts and actors apply different distinctions between hazards and impacts. For a climate scientist, a change in river discharge can be understood as impact, whereas for an insurer, a change in the probability of exceedance of certain water levels in flood prone areas or a change in value at risk is an impact.

In this report hazard data are concerned with measured or forecast weather or climate conditions (temperature, precipitation, wind speed, etc.) and their statistical properties. Furthermore, also flooding related data (discharges, storm surges) and soil properties (moisture, frozen/unfrozen state) can be part of the description of certain hazards.

For impact data we distinguish several levels as there is a diversity in the understanding of what 'impact' encompasses. Table 1 provides an overview starting from a basic level (1) where only the damage proneness is indicated, via initial impact probabilities (2) and volume indications of physical impacts on economic assets (3) to more precise physical and monetary damage inventories (4).

Several climate services reported in D2.3 belong to levels 1 and 2. This report focuses mainly on level 3 and to some extent level 4 impact data.

Table A Distinguishing between different levels of impact data

Level	Extent of impact inclusion	Examples
1.	Damage proneness of weather conditions (e.g. various indexes)	Exceedance probability of critical wind speeds; Drought indexes
2.	Initial-impact probabilities (e.g. ~60% likelihood water level > X meters in location N)	Flood maps – observed cases and climate change projections Heat maps of built-up areas - observed cases and climate change projections
3.	Observed or modelled physical impacts on production, capital stock, public health, etc…	Inundation maps showing water depths, real estate, and land use – observed cases and climate change projections
		Drought index map with deviations in crop specific yields per ha compared to normal years – observed cases and climate change projections
4.	Observed and attributed economic impacts	Reported damage (in quantities and (crudely) in euros) based on visual inspection of the degree(s) of damage in an area - Based on rescue team reporting - Based on remote sensing
		Reported damage (in quantities and euros) based on insurance claims
		Modelled damage (in quantities (and euros)) based on physical features of hazard (depth, wind speed) and of affected area (number of houses, companies, tree stands, people, etc.)
		Inclusion of health care costs and longer-term health effects, requiring high resolution population and vulnerability data

		Inclusion of add-on effects, e.g. related to access limitations and temporary housing, as well to price effects (for repair cost, crops, etc.) – distribution of winners and losers
5.	Impacts on the insurance sector:	volume and pay-out ratio of insurance claims by event, by event type over multi-year periods, by country, etc.
		insurability, affordability and coverage of insurances by country (by hazard)
6.	Expanding from pure monetary effects to broader well-being effects	Measures of environmental damage; Measures of resilience (e.g. time recovery)
7.	Overall (regional) macro-economic impact in the short term (first year) and long term (after 5~7 years)	Requires reliable, versatile, detailed statistics and validated modelling. Enables attribution to initial impacts, weaknesses, and recovery strategies.

During a project-internal meeting in May 2025 PIISA consortium members were consulted on their views concerning definitions of impact data, based on the above listing. Views differed considerably. Nevertheless, a consensus view was that for many adaptation and insurance purposes (at least) **level 3** seems required. Yet, for some private sector actors disclosure of the damage sensitivity of their production or their capital stock may affect their profitability, whereas sometimes national/societal security may call for limits on disclosure. In that case, **level 2** supplemented with in-house analysis may be preferred. However, abundant recourse to level 2 may hamper societal learning and result in less avoided cost (e.g. in case of infrastructure companies). Insurance companies themselves possess damage and claim data at **level 3 and 4** from their own customer base. Due to privacy legislation and competition concerns such data are usually not available for third parties, at least not at high resolutions. Therefore, no such datasets are included in this report. There are nevertheless examples of conditional sharing of such data (Ceolotto et al 2024), and more sharing of such data could be beneficial for insurance innovations and associated climate services.

Finally, for *overall effective*, regional and/or sectoral, adaptation and associated insurance there should also be a reasonable availability of **levels 4 and 5**, albeit at coarser resolutions or higher aggregation levels.

3.2 Selection criteria

Both observed impacts and projected impacts are relevant. Usually observed impacts have a high spatial and temporal resolution, even though there may be a difference in aggregation levels between publicly available and limited access impact datasets.

The most important feature is **data quality assurance**, i.e. verified data from an acknowledged authority or expert organisation. Data sets should also have a sufficiently specified set of metadata, such as area and time period covered, spatial and temporal resolutions, origin of measurement/observation and associated uncertainties, and possible exclusion of some type of effects.

Data sets should be at least to some extent **accessible to third parties, b**ut do not need to be free of charge. Descriptions in languages other than English is admissible.

Preferably datasets cover **at least one EU Member State**. Regional datasets are of less interest due to limited usability elsewhere. An exception are regional impact data with unique properties or covering impacts barely covered by other datasets.

For observed impacts the **period of observation** should be sufficiently long (i.e. at least 10 years). For projected impacts it is preferable to have more than one scenario per hazard and area.

The topical focus should concur with the PIISA topics, being: impacts of floods (urban, agriculture), impacts of wildfires (forests), impacts of urban heat stress (indicators still open, e.g. mortality and morbidity effects, energy cost of cooling, property value discounts), impacts of windthrow (forests, this may need inclusion of follow-up biotic risks), impacts of clay soil shrinkage (urban), impacts of drought (agriculture).

For some of these topics also data on associated vulnerability (in addition to impacts) can be included – it has not been discussed on what grounds certain vulnerability data will be included.

The purpose of the catalogue is to illustrate that sufficient impact data can be found which can be linked to hazard data and are also used for risk analysis and underpinning adaptation and resilience planning. There is no point in striving for completeness, but the collection should have sufficient diversity.

Elements to be included in the metadata:

- **Generic**: hazard/'sector', dataset name, location, brief description
- **Contents**: physical impacts (on capital stock, production, health, ecology), costs
- **Extent:** covered period, spatial resolution, countries/regions covered,
- **Access**: data access conditions, languages

3.3 Metadata and documentation standards

The management, sharing, and documentation of data within the PIISA project follows rigorous standards to support the project's ambition of co-creating innovative, context-sensitised insurance products. Given that PIISA serves a wide range of stakeholders—from citizens and farmers to major insurance companies and EU-level policy frameworks—the standardisation of metadata and project documentation is critical. This section outlines the principles, conventions, and practices adopted across the project to ensure that data on climate-related risks, damage, and losses is seamlessly integrable, verifiable, and highly reusable.

3.3.1 Metadata Specifications for Climate Risk and Impact Data

To facilitate a smooth translation of climate hazard models into insurable risks and adaptation strategies, the metadata accompanying PIISA datasets must comprehensively describe the properties and provenance of the data.

Standardised Hazard and Extreme Indicators

When handling datasets related to weather and climate hazards, PIISA leverages established methodologies like the Extreme Climate Indicators (ECI). The metadata for these generated datasets must reflect key structural assumptions:

- Indicators must be standardised so they can be aggregated and compared across larger geographical regions.
- Datasets must be constructed from data that satisfy strict risk transfer criteria.
- This entails providing metadata that proves a consistent, sufficiently long, and high-quality historical record that will continue to be produced objectively in near real-time.

Harmonisation of Damage and Loss Data

Addressing the highly scattered and incomplete nature of existing damage and loss sources requires robust metadata frameworks. PIISA datasets aim to follow operational guidance developed by the EC Loss and Damage working group established by the Joint Research Centre (JRC) to harmonise data collection. Additionally, metadata standards align with the 2019 UNECE Recommendations on the Role of Official Statistics in Measuring Hazardous Events and Disasters. By aligning with these frameworks, PIISA ensures that the datasets are readily integrable with major European platforms, such as the JRC Risk Data Hub, EEA CLIMATE-ADAPT, and the Copernicus Climate Change Service (C3S).

3.3.2 Dynamic Documentation: The "Living Documents" Approach

Given the iterative nature of the project's co-design phases—particularly within the Pilots exploring Cities and Well-being, Food and Agriculture, and Forests and Forestry—traditional, static documentation is insufficient.

To resolve this, PIISA applies a "dynamic documentation" process where documentation is shareable among partners and continuously updated. These records are referred to as "living documents" within the PIISA framework. This dynamic process promotes immediate actionability, enhances cross-disciplinary collaboration, and drives continuous improvement throughout the pilot development cycles.

PIISA thoroughly documents all iterations—called "Loops"—of pilot development using these living documents. This approach guarantees that feedback collected from stakeholders, user interactions with the Climate Adaptation Dashboard, and iterative adjustments to parametric insurance thresholds are recorded contextually.

3.3.3 Code and Software Documentation Standards

A substantial component of the PIISA infrastructure involves the development of risk-sharing algorithms, the granular climate adaptation dashboard, and associated software tools.

To uphold transparency and encourage broad adoption:

- All code developments generated in PIISA is openly shared, barring components that are strictly proprietary.
- For hosting and documenting software, Git repositories are utilised.
- These repositories act as centralized hubs for both users and developers, ensuring that the software architecture, installation instructions, dependencies, and version histories are explicitly documented, which directly supports the further uptake of the developments.

4 Catalogue of impact, damage and loss data

4.1 Overview of the impact data inventory

Table 4.1 presents the identified impact data sets. Observed impact data concerning heat stress are rare because of attribution challenges (e.g. Ruuhela et al 2020). Furthermore, such data are usually for large spatial scales, e.g. regional. Similarly, harvest losses due to adverse weather have attribution challenges. Schmitt et al (2022) and Beilloun et al (2020) show for Germany and Europe respectively that yield response parameters can be estimated, but the uncertainties are large due to a large number of factors which are not or poorly observed. For the other hazards observed physical impact data do exist, but may have limited access. For forest related damage such data are mostly either an annual summary or a case study. In some countries, e.g. Finland, forest monitoring systems enable high resolution simulation of damage risk for a certain period. For flooding related damage, high resolution observed damage and cost are rarely available, but by combining flood area and flood depth with real estate and population data, reasonable estimates of the number of affected homes and people and approximate direct cost can be made. The same applies to projected flood risks and sufficiently high resolutions. It should be reiterated that the table below only includes impact data that refer to the hazards dealt with in the PIISA project pilots.

Table B Overview of impact data sets

Hazard; measured effect	**sector**	**name & location of dataset**	**brief description**
Heat stress	**Urban**		
Cooling degree days **Level 2**	Urban	Heat Roadmap Europe; Heat Roadmap Europe Used in the Green Roof pilot.	CDD projections, taken from Deliverable D3.3 of Heat Roadmap Europe (“Baseline scenario of the heating and cooling demand in buildings and industry in the 14 MSs until 2050”). Used 2050 projections of CDD for Finland, Netherlands and Italy.
Urban Heat Island **Level 2**	Urban	Climate Impact Atlas - UHI map	Zoomable UHI map – current climate / 2050
Warm nights **Level 2/3**	Urban	Climate Impact Atlas - warm nights map	Zoomable map – number of warm nights/year – current climate / 2050 Netherlands – The map is outdated, and a new version will be available by June 2026

Clay soil shrinkage			
CSS risk of address of choice **Level 4**	Real estate	Errial	Localized geophysical risk data retrieval service for buildings and infrastructure
CSS risk (and other) **Level 3**	Real estate	GASPAR	identification of affected municipalities, risk zoning, prevention plans and land-use restrictions related to exposed assets
Drought / Soil moisture deficit **Level 2**	Real estate	Soil Wetness Index (SWI) from the Météo-France public datasets portal	Indicator derived from meteorological data and soil water balance modelling, representing relative soil moisture conditions compared to climatology.
CSS precursor index **Level 2**	Real estate	Climate Dryness Index (CDI) – developed in PIISA (to be added to JRC Risk Data Hub)	PIISA-developed climate index designed to characterise combined drought and heatwave relevant for clay soil shrink–swell processes.
Pluvial floods	**Urban**		
Observed flood damage **Level 3/4**	Real estate; infra; etc.	Flood damage statistics (Tulvavahinkotilastot), also other flood types Microsoft Power BI	Summary statistics of observed damage over the period 1995-2015 by type of object by municipality and type of flood
Modelled flood damage **Level 3/4**	Real estate; infra, people	Flood damage projections for near future, also other flood types. Microsoft Power BI	Estimated quantity of affected people, buildings and roads per flood risk area, by return time
Pluvial flood depth **Level 3**	Real estate; infra	SYKE storm water map (Beta version 2024)	Zoomable map application for pluvial flood risks in built-up areas in Finland for two levels of extreme downpours
Pluvial flood damage **Level 3**	Real estate	Model simulation of inundation and its reduction due to green roofs in Amsterdam	See box to the left
Water depth after downpour **Level 3**	Real estate; infra	Climate Impact Atlas – water depth of modelled downpours zoomable map application	Flood depth associated with several short severe precipitation events in the Netherlands
Drought			
Drought **Level 1/2**	Agri-culture	Combined Drought Indicator (CDI) from the European Drought Observatory	Developed by the European Drought Observatory, it integrates precipitation anomalies (SPI), soil moisture anomalies, and vegetation stress indicators to classify drought conditions into warning levels.
Indicator for yield loss risk	Agri-culture	Drought index - Yield loss due to lack of irrigation -	Yield loss map due to insufficient irrigation under climate change

due to lack of precipitation & irrigation **Level 2/3**		developed in PIISA (to be added to JRC Risk Data Hub)	
Windthrow			
5 year wind damage risk in Finland **Level 3**	forests	LUKE forest damage risk monitoring at high resolution	Zoomable map application showing 5 year wind induced damage probability (also snow load and bark beetle damage risks can be shown)
Damage ranking based windthrow event catalogue **Level 2**	forests	FORWIND (article); Dataset:	database of wind events in European forests over the period 2000–2018
Wildfire			
Simulation model MTT **Level 3**	forests	Simulated wildfires MTT model	Applied to Pilot 5 (Wildfire insurance in conjunction with fire mitigation measures) see Deliverable 3.13 (Kochar et al 2026)
Simulation model WISE **Level 3**	forests	Simulated wildfires WISE model	Applied to Pilot 5 (Wildfire insurance in conjunction with fire mitigation measures) see Deliverable 3.13 (Kochar et al 2026)
Historically burned area **Level 3**	Forests	MODIS burned area	Historical burned area from MCD64A1 Version 6.1 product at 500 meters resolution over the 2001-2024 period.
Many hazards – Integrated			
Europe – ClimateADAPT		Floods, heat stress, drought, wildfires, soil stability, ground water, water quality, windstorms, adaptation options, built environment, population, costs of hazards	Floods, heat stress, drought, wildfires, soil stability, ground water, water quality, windstorms, adaptation options, built environment, population
Netherland – Climate Impact Atlas		Floods, heat stress, drought, wildfires, soil stability, ground water, water quality, windstorms, adaptation options, built environment, population	Often high-resolution grids (100 – 500 meters)

4.2 Discussion

The included impact data illustrate that with some effort impact data can be found. Data sets cover often only one country, and in various cases only the national language version is available for data retrieval and metadata. Impact data concerning floods and clay shrink swell tend to have more detailed data on physical impacts and cost impacts (more Level 3 and 4 ratings), as these effects are spatially more specific. To some extent that also seems to apply for wildfire (Level 3 scores), even though the spatial precision is lower. Drought and heat stress (mostly Level 1 and 2 scores) concern quite different types of effects spreading over larger scales, and with a significant – not necessarily well observable – vulnerability component.

So far, the only more integrated impact data system found is the Climate Effect Atlas for the Netherlands. The comprehensiveness, user-friendliness, and flexibility set an example for other countries. Climate ADAPT covers all EU Member Countries, as well as EEA associate members. Climate ADAPT includes a very wide range of information, including reports, policy overviews, and data. Data, reports, and map applications on impacts and cost figures can be found, but finding the most suitable alternative is not always easy due to the many layers and cross-linkages. For this report, the most relevant sections within Climate ADAPT are the Adaptation Dashboard and the Climate Impact and Preparedness Portal. Some sections are less up to date and data are often presented at regional or national level, rather than at higher resolutions.

JRC Risk Data Hub provides a generic map application for hazard risks, including floods, extreme heat, wildfires, and windstorms, combinable with data on population, land use, and vulnerability. In many cases the spatial resolution is reasonably high (e.g. 20 km grid). In some cases it is national. The same hub provides a separate application on incurred economic losses (only direct cost) since 1980 until the most recent completed year (currently 1980-2024). Data can be represented in graph and map mode for the entire EU as well as for a selection of Member States, for one or more hazards. The maps provide only data at the national level. Therefore the graphs are often more informative. Next to monetary losses, the number of casualties can also be shown.

Both the data in the JRC Risk Data Hub and those in Climate Adapt can be downloaded (for a certain topical and spatial selection). Both portals also offer quite elaborate metadata.

According to Bountzouklis et al (2025), in their recent review of impact data availability, coverage of different types of impacts and findability of such data in Europe is still full of shortcomings.

4.3 Usage example

Example 1. Climate Impact Atlas – zoomable warm nights map Netherlands

Choose the icon for the **heat theme** and select the option '**Warm nights**'. This selection uses the so-called 'viewer' option of the portal, a general zoomable map application in which all effects, vulnerabilities and adaptation options are selectable. In addition, through the option 'map narratives' background and deepening information on the effect are provided as well as illustrations of how the map information can be used.

The expected level for the entire country in present climate is shown when opening the option warm nights (figure 3.1). Subsequently, one can zoom to a particular city. Outside cities the number of warm nights is and remains typically lower. The example below focuses on The Hague (figure 3.2) with present climate (left) vs. 2050 (right). Apparently, the expected annual number of warm nights in The Hague by 2050 is about two weeks more than the current level. The application allows to add layers referring to vulnerability, such as the share of people aged 75+ by neighbourhood.

The map data underneath this application will be updated during the first half of 2026.

Figure 4.1 Opening view of Climate Effect Atlas for the warm nights indicator

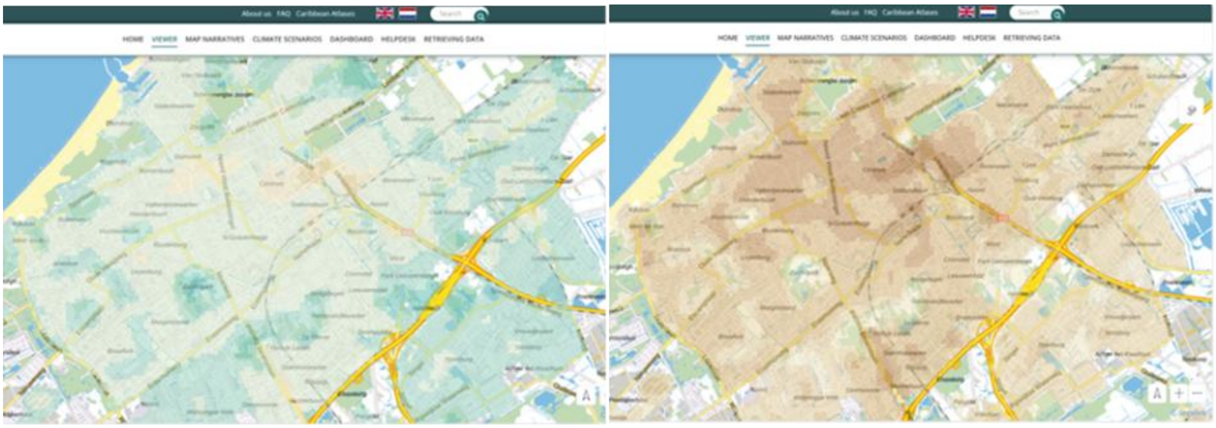

Figure 4.2 Zooming to The Hague – number of warm nights in present climate (left) and in 2050 (right)

Example 2. Observed flood damage costs Finland

The application opens a dashboard with text in Finnish (Figure 3.3). Results can be shown for all types of floods as well as for each type separately. The damage data cover the period 1995-2015. The default representation is aggregate values for the entire country, but one can click on a particular municipality (if it has had flood damage) or on a particular year (a bar in a graph). The other elements in the dashboard adapt to the choices made.

The pie chart in the right upper corner shows costs per sector for the selection made. The coloured rectangular fields in the lower right corner of the dashboard represent costs per region by type of flood. Fluvial floods are the predominant type of floods in Finland.

All in all, by international comparison the observed flood costs are low in Finland, usually not exceeding 5 million euro in a given year. Yet, these statistics not necessarily cover all costs incurred.

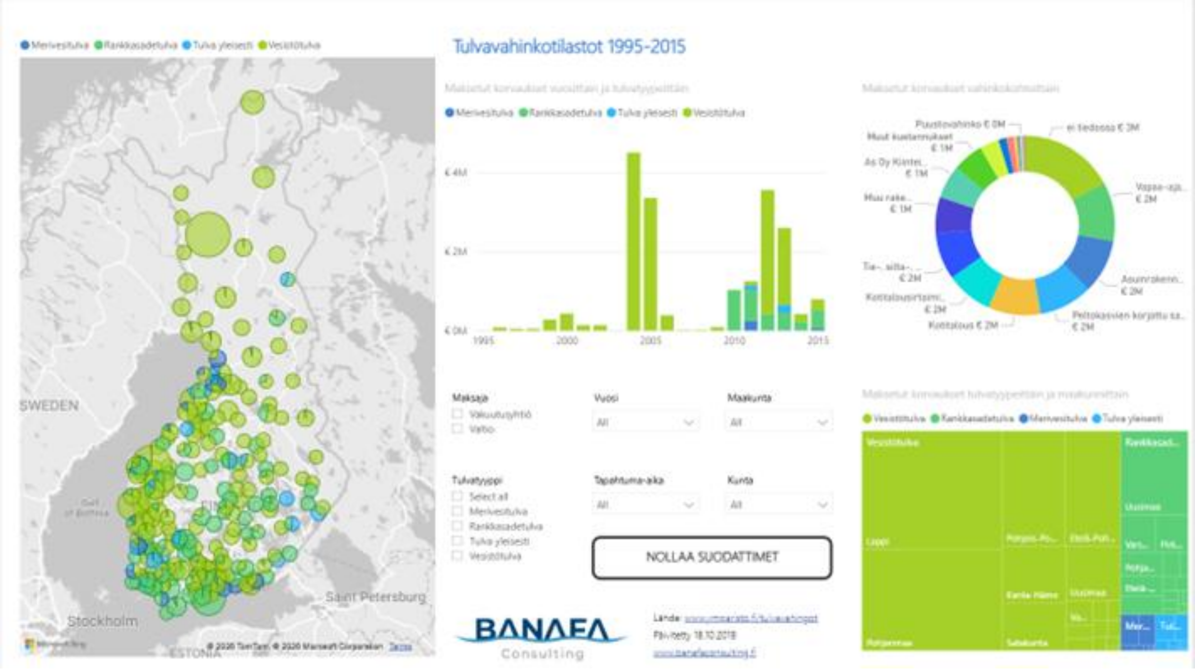

Figure 4.3 Combined map and graph application for costs of all flood types in Finland

5 Integration with the Risk Data Hub (DRMKC)

This section outlines the strategic rationale and the technical workflow adopted by the PIISA project to integrate its generated datasets and risk indicators into the Disaster Risk Management Knowledge Centre (DRMKC) Risk Data Hub (RDH). The RDH hosts data pertaining to disaster risk and its key components: hazard, exposure, and vulnerability, alongside disaster losses.

5.1 Rationale and General Background

The integration of PIISA datasets into the RDH serves as a cornerstone for achieving the project's broader objectives of making adaptation smarter, swifter, and more systemic across the European Union. The DRMKC RDH is a multi-hazard geo-portal designed to act as a vital link between scientific research and policy implementation at various levels. Its primary objective is to foster collaboration between scientists and end-users, enabling seamless knowledge exchange and informed decision-making. In the context of the PIISA project, developing and implementing mechanisms to collect and share comprehensive, harmonised data on climate-related risks and losses is a Specific Objective (SO 2). PIISA contributes directly to updating the RDH with novel, open-source risk indicators, including:

- a compound index called Climate Dryness Index to assess drought and heatwave conditions, and their compound effects, relevant for soil-related risks;
- an indicator called Standardized Windstorm Index to characterise extreme wind events and support the analysis of wind-related impacts on forestry;
- hail Index to capture the occurrence and intensity of hail events, particularly relevant for agricultural losses;
- Thunderstorm and Severe Thunderstorm Day Indices to provide proxies for convective storm occurrence and associated hazards (e.g. lightning, gusts, hail);
- Wildfire-related indicators and datasets (e.g. wildfire catalogues) to support the assessment of fire risk and its implications for the forestry sector;
- precipitation-based indicators (e.g., the Three-Month Dry Accumulation Probability Index, the Yield Loss Drought Index, and the Standardized Precipitation and Growth Index), to assess rainfall deficits and water stress conditions and their potential impacts on crop productivity under rainfed conditions.

By supplying these updated indicators for current and future climates, PIISA enables the modernization of insurance practices—helping align pricing and offerings with the realities of climate change while showcasing the added value of shared EU impact databases. Ultimately, integrating PIISA's outputs with the RDH ensures that the data is highly accessible for risk reduction, resilience management, and parametric insurance modeling.

5.2 Workflow for Dataset Integration into the RDH

Based on several teleconference meeting with JRC officials it has been agreed that a page for the PIISA project will be created in the Hosted Projects section of the RDH portal which is available at the following web address:

https://drmkc.jrc.ec.europa.eu/risk-data-hub#/external

To ensure successful ingestion and interoperability with other European datasets, the following workflow and standardisation guidelines were provided by the RDH.

5.2.1 Spatial Extent and Georeferencing

The data available in the RDH covers the geographical area of the EU 27 and select European Free Trade Association (EFTA) countries.

- All geospatial information should utilise the Nomenclature of Territorial Units for Statistics (NUTS) from Eurostat. Stakeholders should ensure that data is referenced using the appropriate NUTS codes and include information about the NUTS version.
- As of the current release, the RDH reports all data and indicators at the level of the NUTS version 2021.

5.2.2 Formatting Requirements by Data Type

Data must be clearly categorised and formatted based on its spatial nature before submission:

- **Vector Data**: Used for discrete features like boundaries or infrastructure, vector data should be provided in ESRI's Shapefile (.shp) or Geodatabase (.gdb) formats. The required coordinate system is WGS 84 / Pseudo-Mercator (EPSG: 3857).
- **Raster Data**: Used for continuous phenomena like temperature, raster data should ideally be provided in GeoTIFF format (.tif) using the WGS 84 / Pseudo-Mercator (EPSG: 3857) coordinate system. It is strongly recommended to provide a Styled Layer Descriptor (SLD) file (e.g., generated via QGIS) to standardize the visual presentation of the data, such as color gradients and classes. It was agreed that NETCDF is also an acceptable file format
- **Tabular Data**: Non-geospatial datasets must be shared in CSV format. These files must include a specific column denoting the NUTS code for the region, along with the NUTS version year.

5.2.3 Metadata Standards

Comprehensive metadata is recommended for all submitted datasets—including raster fields and tabular columns.

Datasets should be described in accordance with the Risk Data Library Standard (RDLS), an open metadata standard developed by GFDRR and the World Bank specifically for climate and disaster risk assessments. This standard focuses on accurately describing hazard, exposure, vulnerability, and loss datasets, simplifying the process for end-users to identify and confidently utilize the data.

5.2.4 Upload and Hosting Process

The PIISA datasets will be uploaded through a dedicated ftp server. However, the RDH is a curated portal, meaning the datasets need to be preprocessed by DRMKC officials before being visualized on the portal. Specifically, the process envisages the following steps:

1. **Verification**: Datasets are securely shared with the RDH team for a comprehensive verification of data integrity.

2. **Display Selection**: Upon receiving the data, the RDH team reviews it and selects the most suitable hosting tool, typically deploying an ArcGIS Dashboard or an app developed with ArcGIS Experience Builder.
3. **Direct Redirection (Optional)**: In specific instances where PIISA partners have already built robust project materials using ESRI tools, the RDH can be configured to redirect visitors directly to the externally hosted dashboards.

6 Conclusions

Weather- and climate-related impact data across Europe remain fragmented and unevenly available. Impact datasets are often held by different organisations, collected using different methodologies, and reported at varying spatial scales. In addition, many available datasets represent impact proneness or hazard exposure rather than actual impacts such as physical damage, economic losses, or public health effects. This heterogeneity limits their immediate usability for climate risk assessment and insurance applications.

This deliverable has presented a selection of national and exploratory impact datasets, organised according to the extent to which they represent observed or projected impacts. The inventory illustrates that, although useful impact datasets exist in several EU countries, their availability and harmonisation remain limited. Improving the accessibility and comparability of such datasets would significantly support the development of climate adaptation strategies and innovative insurance solutions.

In parallel, the PIISA project has developed several climate indices that function as impact precursor data, supporting the analysis of potential damage risks at higher spatial resolutions. To facilitate their reuse by a wide range of stakeholders, these indices have been integrated as open datasets into the Joint Research Centre’s Risk Data Hub. The datasets comply with existing risk data standards and have been harmonised in terms of spatial coverage and aggregation level using the EU NUTS classification system.

By combining an overview of existing impact datasets with the integration of newly developed climate indices into a European data platform, D2.1 contributes to strengthening the data foundations required for climate risk analysis and climate-informed insurance services. The work carried out under Task 2.1 therefore supports the broader objectives of PIISA to improve the availability, transparency and usability of climate risk data across Europe.

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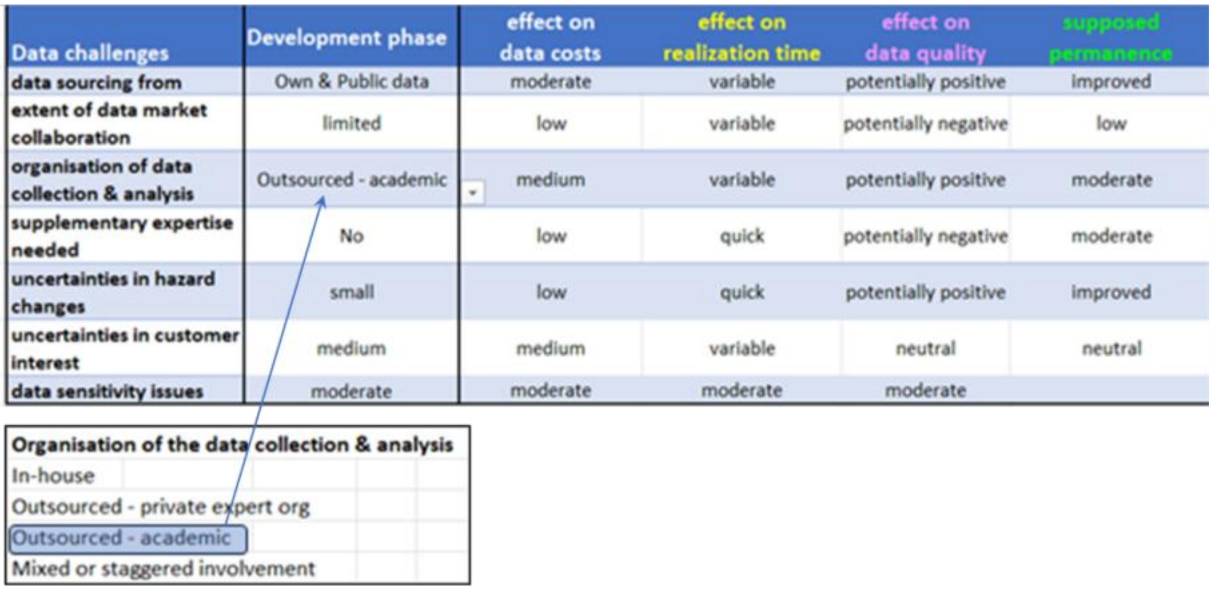
Appendix 1 – Value Chain Analysis of Data

Based on the literature review of D1.1 (Ceolotto et al 2024) and additional works (Susha et al 2023; Timms et al 2022; Bonvino & Giorgino 2022; Bergemann and Ottaviani 2021; Enders et al. 2020), and feedback from the Pilots and insurance companies a stylized value chain was established as presented in §2.3 and Figure 2.1. Innovation cost factors consist of data costs, data quality, realization time, and permanence of key inputs. These cost factors, in turn, are driven by decisions on the scope of data sourcing, degree of data market collaboration, internal vs. external expertise use, privacy protection, and uncertainties in hazard changes and customer interest. This is summarized in Figure A1.1, representing a pivot table. For each cost factor alternative approaches can be chosen, especially driven by the extent to which the company prefers internal resourcing over data sharing and use of external expertise. Internal resourcing can be associated with a defensive stance.

Figure A1. 1: Pivot table for strategic data choices, including example of underlying options, and associated effects on data cost, realization time, data quality and overall permanence of the required data sets



Data challenges	Development phase	effect on data costs	effect on realization time	effect on data quality	supposed permanence
data sourcing from	Own & Public data	moderate	variable	potentially positive	improved
extent of data market collaboration	limited	low	variable	potentially negative	low
organisation of data collection & analysis	Outsourced - academic	medium	variable	potentially positive	moderate
supplementary expertise needed	No	low	quick	potentially negative	moderate
uncertainties in hazard changes	small	low	quick	potentially positive	improved
uncertainties in customer interest	medium	medium	variable	neutral	neutral
data sensitivity issues	moderate	moderate	moderate	moderate	

Organisation of the data collection & analysis
In-house
Outsourced - private expert org
Outsourced - academic
Mixed or staggered involvement

The above pivot table can be used in a qualitative way, using scores to enable tentative comparisons of data strategies. The above pivot table can also be linked to a set of cost equations translating the choices into cost estimates.

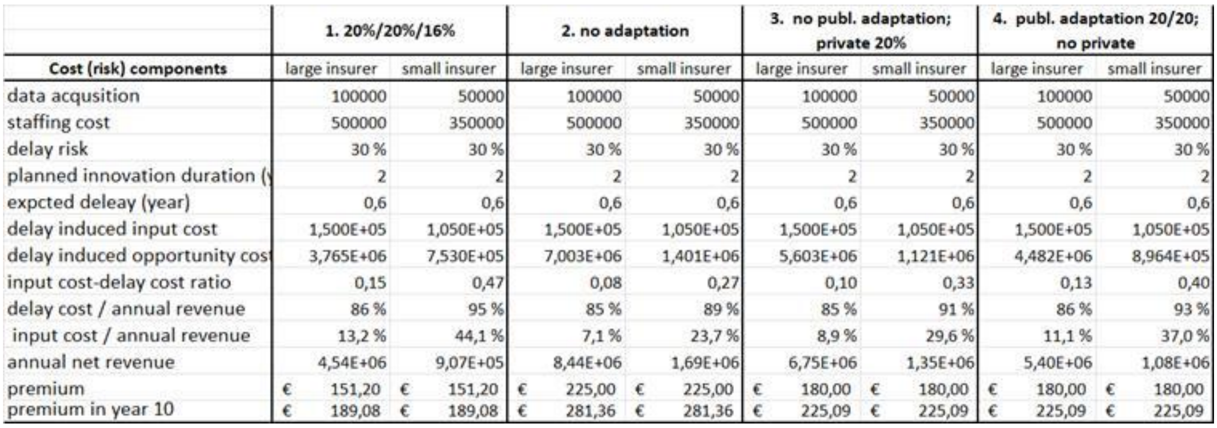
In the qualitative mode, for each of the cost drivers a conditional function is applied giving a rating dependent on the choice made for the organisational factor concerned. Subsequently, qualitative ratings per organisational factor can be assigned a score, indicating the tentative difference as compared to the best score. Scores can be derived from administrative data either directly or moderated through a group decision process. A complication is that some choices for some of the organisational factors are interdependent, that is narrowing down the relevant choice range for another factor. Also, to obtain credible ratings these should be based on earlier studies or some kind of group decision process.

In this appendix a simple quantification is applied to illustrate that access, availability and quality of hazard *and* impact data can negatively affect the pace of innovation for adaptation aware insurances.

Based on the indicative figures for typical insurance company size and market shares in Europe from Deliverable 1.4 (Lameh et al 2024) a typical small and large insurance company are defined with product-specific residential customer potentials of 100000 and 500000 respectively. Furthermore, a climate change driven increase of 1% in annual probability (0.005 in year 1) is applied.

First an annual hazard probability, number of potentially exposed households, and unmitigated average damage per affected household (object) are defined. Subsequently, the effects of public and private adaptation are defined. Public adaptation can reduce both the number of exposed households and/or the average damage per households. The private adaptation affects only average damage per household. The resulting stylized insurance cost scenario is shown in Table A1.2 (at the end of Appendix A1) for a large insurance company. Table A1.1 focuses on the consequences for the innovation cost and average premiums distinguishing between small and large insurance firms.

Table A1. 1: Effects of four levels of adaptation effort for a given hazard on premium levels and innovation costs for a stylized small and large insurance company (in €).



	1. 20%/20%/16%		2. no adaptation		3. no publ. adaptation; private 20%		4. publ. adaptation 20/20; no private	
Cost (risk) components	large insurer	small insurer	large insurer	small insurer	large insurer	small insurer	large insurer	small insurer
data acqusition	100000	50000	100000	50000	100000	50000	100000	50000
staffing cost	500000	350000	500000	350000	500000	350000	500000	350000
delay risk	30 %	30 %	30 %	30 %	30 %	30 %	30 %	30 %
planned innovation duration (	2	2	2	2	2	2	2	2
expcted deleay (year)	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
delay induced input cost	1,500E+05	1,050E+05	1,500E+05	1,050E+05	1,500E+05	1,050E+05	1,500E+05	1,050E+05
delay induced opportunity cos	3,765E+06	7,530E+05	7,003E+06	1,401E+06	5,603E+06	1,121E+06	4,482E+06	8,964E+05
input cost-delay cost ratio	0,15	0,47	0,08	0,27	0,10	0,33	0,13	0,40
delay cost / annual revenue	86 %	95 %	85 %	89 %	85 %	91 %	86 %	93 %
input cost / annual revenue	13,2 %	44,1 %	7,1 %	23,7 %	8,9 %	29,6 %	11,1 %	37,0 %
annual net revenue	4,54E+06	9,07E+05	8,44E+06	1,69E+06	6,75E+06	1,35E+06	5,40E+06	1,08E+06
premium	€ 151,20	€ 151,20	€ 225,00	€ 225,00	€ 180,00	€ 180,00	€ 180,00	€ 180,00
premium in year 10	€ 189,08	€ 189,08	€ 281,36	€ 281,36	€ 225,09	€ 225,09	€ 225,09	€ 225,09

An insurance company's resource input for an innovation has significant economies of scale. In the stylized example presented here is assumed that for a 5 times larger customer base input cost may be only around 1.5 times larger (a factor 2 for data acquisition and handling and a factor 1.43 for staffing). This can be seen by checking the indicator 'input cost / annual revenue'. For small firms the cost share is 3 to 4 times as large as for large firms. Please note that these are simplified calculations for stylized cases, and therefore both the levels and the comparisons should be understood as *indicative only*. Nonetheless, whereas for large firms the input costs of innovations tend to be small compared to expected revenues from the innovated product, these can already be significant for small firms. However, the input cost as such don't seem to be main reason why good data availability and quality is important. Instead, the opportunity costs of protracted (delayed) innovation projects have a much stronger prohibitive effect on starting product innovations. The opportunity costs consist of two parts: (1) the delay of the start of revenue generation of the aspired product, possibly combined with reductions owing to data quality compromises, and (2) the delay of alternative innovations due to protracted (and increased) innovation efforts of the initial innovation (assuming that protraction does divert innovation capacity from other options). These opportunity costs are much larger than the innovation costs as such. This also explains why many firms review progress and prospects of innovations in subsequent stages and prune the innovation portfolio guided according to best pay-out prospects. In these stylized examples these costs are 7 to 12 times larger than the input costs of innovations, while in reality the difference may well be much larger, notably in large insurance companies. Hence, the lesson from this stylized exercise is that good access, availability and quality of hazard, impact and vulnerability data are especially important for keeping risks for opportunity costs low and thereby enable a higher pace of innovation regarding adaptation aware insurances.

Model underpinning Tables A1.1 and A1.2

- Innovation costs of (C_i) $C_i = C_d + C_o$
  new product i
- Data costs (C_d) -acquisition (*X*), staffing (*L*), equipment(*K*), expertise service (*S)*
- In this case it is assume that *K* is part of *X* and *S* a part of *L*
- Revenue opportunity
- cost (C_o) -the expected missed revenues due to protracted innovation efforts for new product *i*
- delay risk ρ - percentage of originally planned realization time *T*
- Expected revenue (R_i) -expected revenue enabled by innovation of new product *i*
- 15% margin of average annual pay-out
- Realization time (T) -affecting staffing and expertise service cost
- -affecting innovation opportunity cost
- T_p - planned realization time
- T_a - actual realization time
- Delay = $T_a - T_p$
- Innovation effort multiplier (*M*) - the (expected) generated amount of annual net revenue from a given amount of innovation resource input (X, L, K, S)
- Data quality (q) -affecting data cost (new or additional data or analysis)
- -affecting innovation opportunity cost (compromises which reduce product's market appeal)
- Data quality effects are taken into account with respect to attainable reduction (and its uncertainty) of average damage cost due to private efforts, i.e. lower percentages in the column 'trend or effect of measures' in Table A1.2

- $C_{di} = X_i + L_i$ where *i* refers to either large firm or small firm, where X = 50000 or 100000 and L = 350000 or 500000
- $C_{oi} = (\rho T_{pi} + M.\rho.L).R_i$ representing postponement of expected revenue of the envisaged product due to protracting innovation and the opportunity cost of foregoing timely revenues from alternative innovation
- $R_{ia} = h.N_a.D_a.\gamma.(1-\delta).margin$
- where h is annual hazard probability, N_a number of exposed households at adaptation level ‘a’ (none, only public, only private, public and private), D_a the average expected damage per exposed household at adaptation ‘a’, γ is assumed insurance penetration rate, and δ represents the level of deductible (as % of damage), and *margin* refers to the margin added to the premium to ensure a net benefit for the insurance company. Insurances also earn from temporary investment of received premiums (if no large pay-outs occur), but have also cost of re-insurance. Both latter aspects have been left out for simplicity.

Table A1. 2: Stylized insurance cost scenarios for a large insurance company

	trend or effect of	1	2	3	4	5	6	7	8	9	10
hazard probability (annual)	1 %	0,0050	0,0051	0,0051	0,0052	0,0052	0,0053	0,0053	0,0054	0,0054	0,0055
number of households exposed	0 %	500000	500000	500000	500000	500000	500000	500000	500000	500000	500000
exposure after publ. adaptation	0 %	500000	500000	500000	500000	500000	500000	500000	500000	500000	500000
average expected damage/hh	1,50 %	50000	50750	51511	52284	53068	53864	54672	55492	56325	57169
avg. damage after publ. adaptati	0 %	50000	50750	51511	52284	53068	53864	54672	55492	56325	57169
avg. damage after object specific (private) adaptation	0 %	50000	50750	51511	52284	53068	53864	54672	55492	56325	57169
annual expected damage volume (incl. possible		1,250E+08	1,281E+08	1,314E+08	1,347E+08	1,381E+08	1,415E+08	1,451E+08	1,487E+08	1,525E+08	1,563E+08
expected penetration rate		50 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %
max coverage	fixed	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %
expected damage volume covered by insurance		5,63E+07	5,77E+07	5,91E+07	6,06E+07	6,21E+07	6,37E+07	6,53E+07	6,69E+07	6,86E+07	7,03E+07
premium margin	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %	15 %
premium		€ 225,00	€ 230,66	€ 236,46	€ 242,41	€ 248,50	€ 254,75	€ 261,16	€ 267,73	€ 274,46	€ 281,36
premium / damage ratio		0,45 %	0,45 %	0,46 %	0,46 %	0,47 %	0,47 %	0,48 %	0,48 %	0,49 %	0,49 %
10 years premium / damage ratio		4,75 %	4,80 %	4,85 %	4,90 %	4,95 %	5,00 %	5,05 %	5,10 %	5,15 %	5,20 %
product lifetime	10										
net income from premium		8,44E+06	8,65E+06	8,87E+06	9,09E+06	9,32E+06	9,55E+06	9,79E+06	1,00E+07	1,03E+07	1,06E+07
product income over its lifetime		9,46E+07									

Appendix 2 Full table of selected impact data

Hazard or measured effect; Level	sector	name & location of dataset	brief description	Included physical impacts	Included costs	Covered period & countries	Spatial resolution	Access
Heat stress	**Urban**							
Cooling degree days **Level 2**	Urban	Heat Roadmap Europe; Heat Roadmap Europe	CDD projections, from D3.3 of Heat Roadmap Europe ("Baseline scenario of the heating and cooling demand in buildings and industry in the 14 Member States until 2050"). Used 2050 projections of CDD for Finland, Netherlands and Italy.	Yes	No	2050	National	Public
Urban Heat Island **Level 2**	Urban	Climate Effect Atlas – zoomable UHI map https://www.klimaateffectatlas.nl/en/viewer	Zoomable UHI map – current / 2050 / 2100 Netherlands	Affected built-up area and population	no	2020 2050 2100	~ 500m	Public
Warm nights **Level 2/3**	Urban	Climate Effect Atlas – zoomable warm nights map https://www.klimaateffectatlas.nl/en/viewer	Zoomable map –number of warm nights/year current / 2050 / 2100 Netherlands	Affected built-up area and population	no	2020 2050 2100	~200m	public
Clay soil shrinkage								
CSS risk of address of choice **Level 4**	Real estate	Errial https://errial.georisques.gouv.fr/#/	buildings, infrastructure		no		municipality	

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CSS risk (and other) **Level 3**	Real estate	GASPAR https://www.data.gouv.fr/datasets/base-nationale-de-gestion-assistee-des-procedures-administratives-relatives-aux-risques-gaspar/	identification of affected municipalities, risk zoning, prevention plans and land-use restrictions related to exposed assets		no	several decades	municipality	public
Drought / Soil moisture deficit **Level 2**	Real estate	Soil Wetness Index (SWI) from the Météo-France public datasets portal (https://donneespubliques.meteofrance.fr/?fond=produit&id_produit=301&id_rubrique=40)	Indicator derived from meteorological data and soil water balance modelling, representing relative soil moisture conditions compared to climatology.	Indirect (soil moisture anomaly proxy)	No	1960-2022	8 km	public
CSS precursor index **Level 2**	Real estate	Climate Dryness Index (CDI) – developed in PIISA (to be added to JRC Risk Data Hub)	PIISA-developed climate index designed to characterise combined drought and heatwave relevant for clay soil shrink–swell processes.	No	No	1991 - 2050	9 km	Public (France) limited for other countries
Pluvial floods	**Urban**							
Observed flood damage **Level 3/4**	Real estate; infra; etc.	Flood damage statistics (Tulvavahinkotilastot), also other flood types Microsoft Power BI		buildings, infra, crops, homes	Yes	1995-2015	municipality	public
Modelled flood damage	Real estate; infra, people	Flood damage projections for next decades, also other flood types. Microsoft Power BI		homes, people, buildings infra	No; but can be inferred from	2025	municipality	public

Level 3/4					quantities			
Pluvial flood depth **Level 3**	Real estate; infra	SYKE storm water map (Beta 2024)		homes, buildings infra	No	2025	municipality	public
Pluvial flood damage **Level 3**	Real estate	Model simulation of inundation and its reduction due to green roofs in Amsterdam		Building	Yes	2050	Urban hydrological basins	Upon request
Water depth after downpour	Real estate; infra	Climate Effect Atlas – water depth of modelled downpours						
Drought								
Drought **Level 1/2**	Agri-culture	Combined Drought Indicator (CDI) from the European Drought Observatory (https://drought.emergency.copernicus.eu/)	Developed by the European Drought Observatory, it integrates precipitation anomalies (SPI), soil moisture anomalies, and vegetation stress indicators to classify drought conditions into warning levels.	Yes (vegetation stress proxy)	No	near real-time + historical archive	~5 km (depending on product version)	public
Yield loss due to lack of irrigation **Level ??**	Agri-culture	Drought index - Yield loss due to lack of irrigation	Yield loss map due to insufficient irrigation under climate change					
Drought **Level 1**?	Agri-culture	Three-Month Dry Accumulation Probability Index (DAP150)	The Three-Month Dry Accumulation Probability Index (DAP150) is defined as the probability that the total accumulated precipitation over a consecutive three-month period is less than 150 mm.		no	1993-2026 Iberian Peninsula	1°	Upon request

Windthrow								
5 year wind damage risk in Finland **Level 3**	forests	LUKE forest damage risk monitoring at high resolution	Zoomable map application showing 5 year wind induced damage probability (also snow load and bark beetle damage risks can be shown)					
Damage ranking based wind-throw event catalogue **Level 2**	forests	FORWIND (article); Dataset:	database of wind events in European forests over the period 2000–2018					
Wildfire								
Simulated wildfires MTT model **Level 3**	forests	Simulated wildfires MTT model	Simulated wildfires based on MTT model for different adaptation scenarios for the pilot area in Portugal	No	No	Stochastic (reference period 2001–2024)	100 m	
Simulated wildfires WISE model **Level 3**	forests	Simulated wildfires WISE model	Simulated wildfires based on WISE model for different adaptation scenarios for the pilot area in Portugal	No	No	Stochastic (reference period 2001–2024)	100 m	
Historical burned area (2001-2024) **Level 3**	forests	MODIS burned area	Wildfires detected from MODIS satellite over the historical period for the pilot area in Portugal	No	No	2001--2024	500 m	Public