



PIISA

Piloting Innovative Insurance
Solutions for Adaptation

D3.5 Preliminary dashboard specification

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Abbreviations and acronyms

Acronym	Description
CSS	Clay shrink swell
CCR	Caisse Centrale de Réassurance
SWI	Soil Wetness Index
SPI	Standardised Precipitation Index
SHI	Standardised Heatwave Index
CDI	Climate Dryness Index
XCF	Extreme Climate Facility
ARC	African Risk Capacity
CMIP6	Coupled Model Intercomparison Project Phase 6
DVF	Government Property Value Request Files
PPRN	Natural risk prevention plan
FPRNM	Fonds de Prévention des Risques Naturels Majeurs
DGPR	Directorate-General for Risk Prevention

Summary

The PIISA Clay Shrink Swell Building Damage Assessor will be an online website designed to educate homeowners about their financial risks associated with inadequate insurance cover for property damage caused by clay shrink swell events. The Clay Shrink Swell Building Damage Assessor is the new name for what is referred to as the climate adaptation dashboard in the Grant Agreement (Task 3.2.2).

The Clay Shrink Swell Building Damage Assessor will be pilot tested in the City of Lyon and then taking account of lessons learned in this process will be replicated in other cities and regions in France. Concurrently with this replication in other cities and regions in France we will research the risk level and insurance framework for other EU countries to identify demand for replication of the Clay Soil Shrinkage Building Damage Assessor in other EU countries.

The Clay Shrink Swell Building Damage Assessor contributes to the following PIISA Specific Objectives:

- SO5: Localised piloting
- SO6: Activating Climate Resilience Dialogue
- SO8: Enabling insurance market growth

This document is the preliminary specification for the Clay Shrink Swell Building Damage Assessor and articulates the methodology and data which will be used in the Clay Shrink Swell Building Damage Assessor. It also summarises the background research on the topic and various aspects of the user journey/interface which may be embedded in the Clay Shrink Swell Building Damage Assessor (although this user journey/interface will be under constant iteration during the software development phase). Finally it includes the contracting information which we will use to instruct a third-party web developer to develop the Clay Shrink Swell Building Damage Assessor.

This document is an outcome from work in Task 3.2.2 which develops one of the five pilots of PIISA WP3. As stated in the workplan, 'T3.2.2 Climate adaptation dashboard for financial assessments' develops a guide to homeowners on financial risk assessments regarding cases of clay shrink swell damage.



1 Background for Clay Shrink Swell Building Damage Assessor

This section describes the nature and extent of the problem of clay shrink swell in France and how insurance cover for homeowners is provided through the national Cat Nat scheme operating with typical multi-risk home insurance. It then articulates the areas where this insurance framework creates risks for homeowners from inadequate insurance cover for property damage caused by clay shrink swell events.

1.1 Background on the causative factors of clay shrink swell

A clay shrink swell (CSS) event can occur if the relevant local factors are present and are combined with the relevant climate factors:

- **Local factors:** These include aspects such as the constitution of the soil (it needs to contain clay), the inclination of the area, the hydrological context of the area, surrounding vegetation etc. (British Geological Survey, Undated). As the name indicates, there must be clay in the soil composition. It is estimated that a CSS event can occur if the soil composition is of at least 10% clay (Boivin et al., 2006).
- **Climate factors:** Triggering factors of evapotranspiration and precipitation from weather events such as droughts, heatwaves and rainfall can potentially trigger a CSS event in areas where the relevant local factors are present.

Annex 1 Causative factors for a CSS event includes a detailed diagram of the relevant factors and processes which lead to a CSS event occurring. 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. The water contained in the clay evaporates and the clay soil shrinks. The drying out of the soil creates both horizontal cracks on the surface and vertical hydromechanical settlement under the weight of the structures (Assemblée Nationale, 2023). Simply put, CSS events occur when a drought is followed by heavy rain, causing soil to move and change shape significantly in a short period of time.

For any given geographic location, the local factors can be assumed to remain relatively constant. Because the local factors for any geographic location can be assumed to remain relatively constant, increasing likelihood of a CSS event occurring is related to climate change and more specifically to the increasing likelihood of the relevant weather events such as droughts, heatwaves and rainfall that can potentially trigger a CSS event.

1.2 Clay shrink swell in France

CSS events mainly affect single-family homes and are widespread in France. It is estimated that 48% of the national territory is at medium or high risk of this phenomenon and around 10.4

million single-family homes are at medium or high risk of CSS events, representing 54% of all single-family homes (Sénat, 2023).

Information Box: Clay shrink swell in the City of Lyon

The location of the pilot test for the Clay Shrink Swell Building Damage Assessor is the City of Lyon, which is situated in the Rhône department, where it is estimated that 26% of houses are potentially subject to CSS risk. Indeed, between 2009 and 2020, 47% of the cities in the department made official requests for the recognition of natural catastrophes due to CSS events. Of these official requests, 45% were not recognised as natural catastrophes (Cour des Comptes, 2022).

1.3 Home insurance cover and natural catastrophes

In France, a national mechanism called Cat Nat is a compensation scheme for homeowners, companies and local authorities for damage caused by natural disasters such as CSS events.

The Cat Nat scheme is based on a dual-guaranteed system:

- insurance companies offer insurance policies to cover properties, and they are reinsured by the Caisse Centrale de Réassurance (CCR) for payouts when a natural catastrophe has been declared; and
- the CCR benefits from a full government guarantee and in return for this guarantee pays the State around €100 million per year (even if there is no payout).

Natural catastrophe insurance is a mandatory contract clause in home insurance contracts. There is an additional premium which is identified individually in the contract and calculated based on a single rate defined by decree. This rate is therefore uniform throughout the country (whatever the degree of risk exposure) and reflects the principle of national solidarity in the face of natural disasters (Sénat, 2023). This rate is applied to the amount of the main premium or contribution, or the amount of capital insured, depending on the type of contract (Code des assurances, article L125-2). In general, this rate is 12% of the price paid by homeowners of home insurance policies.

If a natural catastrophe occurs which is covered by the Cat Nat scheme, the Mayor and then the Prefect must submit an official request to the State to recognise the occurrence of a natural catastrophe through a decree. Once this decree is officially published, the insurer assesses the cost of damage and indemnifies the homeowner and is then reinsured by the CCR.

Further detail on this broad framework is shown in the infographic and accompanying explanation below (and specific details on the process from the homeowner's perspective is in *Section 2 Objectives for the Clay Shrink Swell Building Damage Assessor*).



Figure 1: Framework for declaring a natural catastrophe and state indemnification (CCR, Undated)

When a natural disaster (such as subsidence, flooding or CSS) occurs, the Mayor has 24 months from the date of the event to compile and submit a request to the Prefect requesting the Government to officially declare a natural disaster. Upon receiving the Mayor's request, the Prefect submits it to the Interministerial Commission for examination. The Interministerial Commission reviews the request and, if approved, the Official Journal publishes the list of municipalities recognised by the decree as affected by the natural disaster. This list is accessible on the CCR website.

It is critical to note that homeowners are only covered for damage from a natural catastrophe which is officially recognised as such by the Cat Nat scheme (following the process articulated above). Where the Cat Nat scheme does not officially recognise the natural disaster, the homeowner is not insured for any property damage.

Where there is official recognition of the natural disaster, a loss adjuster is appointed to assess the cost of the damages incurred by the natural disaster. Based on the loss adjuster's assessment, the insurer then indemnifies the insured. To support the insurer in covering these costs, the CCR provides reinsurance in accordance with the Natural Disaster compensation scheme. Finally, to ensure the financial stability of the CCR, the State offers an unlimited guarantee in the event of an extreme natural disaster.

1.4 Recognition of clay shrink swell under the Cat Nat scheme

For a CSS event to be recognised as a natural catastrophe under the Cat Nat scheme, two conditions must be met:

- the affected area has at least 3% of its surface mapped as shrinkable clay; and
- the meteorological conditions that have occurred must be identified as being exceptional periods of drought. This label requires the 3-month average of Soil Wetness Index uniforme to be the lowest or second lowest of a 50-year reference associated with the same month (Bathélmy et al., 2024).

1.5 Concerns as to long term viability of the Cat Nat scheme regarding clay shrink swell

The annual cost of CSS covered by the Cat Nat scheme (i.e. every euro spent on damage caused by a CSS event recognised as a natural catastrophe under the Cat Nat scheme) rose to an average of over €1 billion for years between 2017 and 2020 (compared with €445 million for years since 1982). Indeed, the cost of the 2022 drought alone in the Cat Nat scheme is estimated at between €2.4-2.9 billion (Sénat, 2023).

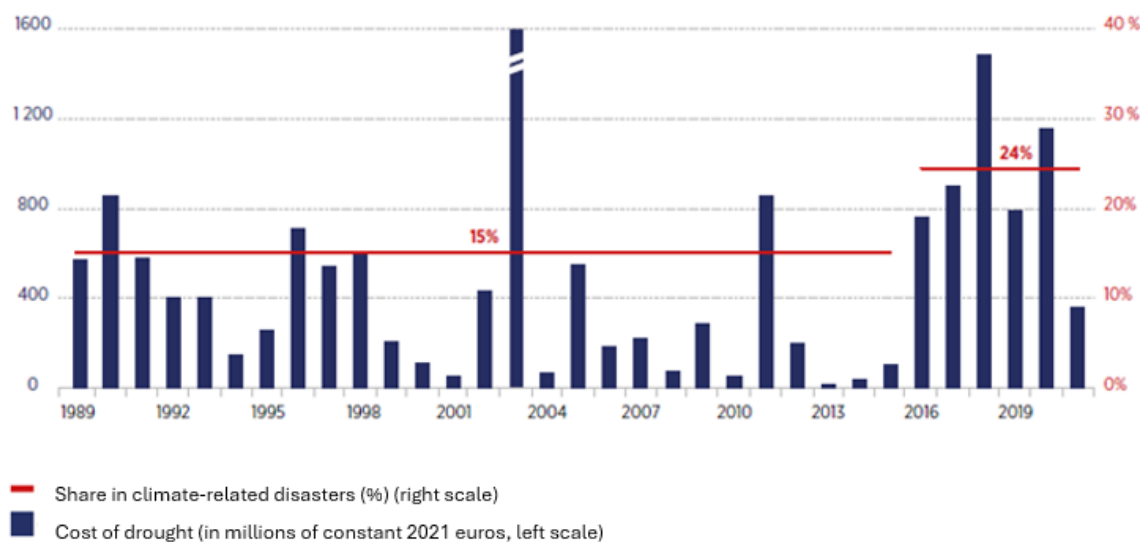


Figure 2: Cost of CSS in the Cat Nat scheme over the years (France Assureur)

It is estimated that the cumulative cost of drought claims between 2020 and 2050 would be €43 billion which represents a threefold increase compared to the previous three decades. In the face of these significant increases in the cost related to CSS event, there are concerns, in the

insurance world and at the national level, that the Cat Nat scheme would no longer be able to generate sufficient reserves to cover claims by 2040 (Sénat, 2023).

1.6 Potential insurance risks for homeowners

Annex 3 Insurance claims for clay shrink swell sets out more detail on the requirements which must be satisfied in relation to insurance cover for CSS and the different steps in the process for an insurance claim when homeowners have suffered property damage resulting from a CSS event. The commentary below articulates the main risk for homeowners which is apparent with this process.

Lack of certainty regarding State recognition of a Cat Nat for clay shrink swell events

Over the last nine years, an average of 50% of requests for official recognition of a CSS event as a natural catastrophe under the Cat Nat scheme have been unsuccessful (Cour des Comptes, 2022).

Official recognition of a natural catastrophe for CSS events can be refused for three main reasons. First, when the case prepared by the Prefect is deferred due to incomplete documentation. Second, although rare, when there is evidence of failure in implementing necessary preventive measures. Third, when the exceptional intensity (see *Section 1.4 Recognition of clay shrink swell under the Cat Nat scheme*) of the event is not proven.

For CSS events, it is particularly challenging to prove the exceptional intensity of the event. This is because CSS can occur over prolonged periods and may not present immediate, dramatic impacts compared to other natural disasters like floods or earthquakes. Indeed, CSS events often have a gradual impact, making it harder to pinpoint a specific moment for the disaster, which complicates the process of demonstrating the exceptional nature of the event.

Starting 1 January 2024, the definition of a natural catastrophe under the Cat Nat scheme has been expanded to include ‘an abnormal succession of significant drought events’ (Bruna, 2023). This modification is significant for CSS events, as it acknowledges that the cumulative effect of multiple droughts can cause substantial damage. By recognising the impact of successive droughts, the new definition better accommodates the nature of CSS, where damage often results from a series of events rather than a single occurrence. This change should improve the chances of CSS events being officially recognised as natural catastrophes, thereby facilitating better support and compensation for affected areas.

Timescale for payouts

The timeline established for the administrative process with the Cat Nat scheme does not align well with homeowner needs. As set out in *Section 1.3 Home insurance cover and natural catastrophes*, the first step is for the Mayor to request state recognition of a natural catastrophe for the affected area, and this request needs to be made individually for each affected area. However, there is a significant delay in this process as each Mayor has up to two years from the occurrence of the disaster to make this request (Georisque, Undated). Once the Mayor submits the request, the Government has two months to analyse the situation and issue the decree recognising the natural catastrophe (Code des assurances, article L125-1).

For homeowners, timing is crucial. They have only 30 days after this decree is issued to report their losses to their insurance company (although they may also do it beforehand). The insurance company has up to three months to compensate the homeowner after receiving the claim, but it must be remembered that if a natural catastrophe is not recognised there will be no insurance payout.

The length of time to receive state recognition of a natural catastrophe (and the consequent length of time to receive compensation) is challenging for homeowners as it prolongs their recovery process and adds to their financial burden. And indeed during the period up to the point that state recognition the homeowner cannot be certain that there will be state recognition and that they will be compensated for property damage. This period of uncertainty is particularly acute for homeowners who cannot live in their property. While emergency rehousing costs are covered even in the absence of recognition of a natural catastrophe, this can leave homeowners in limbo.

In worst case scenario, homeowners might wait up to 2 years and 5 months to start being compensated for their loss.

Failure to adhere to preventive measures

If the property was built without considering the requirements regarding its construction imposed by a natural risk prevention plan (PPRN) or if the preventive work required by a PPRN has not been carried out within five years of the PPRN's implementation, the insurer is not obliged to cover damage caused by a natural catastrophe (Georisque, Undated).

Thus, it is necessary for homeowners to comply with the PPRN, which is a document issued by the State. This document is also attached to the local plan of urbanism issued by the city. For the City of Lyon, it appears particularly difficult to find and access this information. Even if the information exists, it makes it particularly difficult for the homeowner to comply with it, if it is not accessible.

Summary of the risks for homeowners associated with property damage caused by a CSS event

- If a homeowner suffers property damage caused by a CSS event, insurance cover is provided by the typical multi-risk home insurance policy together with the Cat Nat scheme.
- An insurance payout will only take place when the State officially recognises the occurrence of a natural catastrophe under the Cat Nat mechanism.
- Where there has been damage caused by a CSS event but there is no State recognition of a natural catastrophe, there is no insurance payout.
- Even if a natural catastrophe is recognised by the State, there will be no insurance payout if the homeowner has not complied with all preventative measures which are applicable for the property and articulated in the PPRN.
- Even if a natural catastrophe is recognised by the State, the length of time to receive State recognition of a natural catastrophe (and the consequent length of time to receive compensation) is challenging for homeowners as it prolongs their recovery process and adds to their financial burden.



2 Objectives for Clay Shrink Swell Building Damage Assessor

The PIISA Clay Shrink Swell Building Damage Assessor will be an online website designed to educate homeowners about their financial risks associated with inadequate insurance cover for property damage caused by CSS events. This section articulates the specific objectives for the Clay Shrink Swell Building Damage Assessor in the context of this principal objective.

This section and the following ones from 3 to 5 result from Loop 1: Proof of concept of Task 3.2.2 in PIISA workplan, where ‘a methodology to transform the level of vulnerability and exposure to climate risks into financial assessment. The methodology will be based upon open access data sets that cover a variety of domains.’

As demonstrated in *Section 1 Background for Clay Shrink Swell Building Damage Assessor*, there are potential risks for homeowners in relation to inadequate insurance cover for property damage caused by a CSS event. At the same time it is estimated that 48% of the national territory in France is at medium or high risk of CSS events occurring (Sénat, 2023). This means that a significant number of French homeowners are at risk.

These risks in relation to inadequate insurance cover for property damage caused by a CSS event will be compounded as climate change is expected to increase the likelihood of CSS events occurring in the future (see *Section 1.1*).

In this context, the principal objective for the Clay Shrink Swell Building Damage Assessor is to educate homeowners about their financial risks associated with inadequate insurance cover for property damage caused by CSS events. The Clay Shrink Swell Building Damage Assessor will be in online format and will communicate to homeowners various information about the financial (and other) risks they face from inadequate insurance cover.

The Clay Shrink Swell Building Damage Assessor therefore has a different mechanism for change compared to other work activities (in relation to the pilots or otherwise) under the PIISA project. Whereas the mechanism for change for these other work activities can be generally understood to focus on assisting the insurance industry, the Clay Shrink Swell Building Damage Assessor 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.

This focus on homeowners as the target audience/constituency means that the parameters which shape the development process for the Clay Shrink Swell Building Damage Assessor are different. Homeowners must be assumed to be non-experts in relation to the technical aspects of climate change, CSS, insurance cover etc. Therefore communicating to this audience requires transparency, simplicity and clarity. Above all else, the Clay Shrink Swell Building Damage Assessor must be compelling and easy to use so that homeowners will use it. We consider that adhering to these principles will be most effective for getting the PIISA project's



key message across that there is urgent need to reduce the insurance/adaptation gap against CSS risks.

In addition, the focus on homeowners as the target audience/constituency means that the Clay Shrink Swell Building Damage Assessor will not seek to project beyond the base of evidence. For example, the Clay Shrink Swell Building Damage Assessor is not seeking to develop a complex actuarial model of the financial risks for homeowners (as might be appropriate for technical users). Rather, the Clay Shrink Swell Building Damage Assessor will seek 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 seeks 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).



3 User journey for Clay Shrink Swell Building Damage Assessor

This section articulates a high-level skeleton of the user journey we are planning to create for navigating the Clay Shrink Swell Building Damage Assessor. It articulates how users will hear about and be directed to the Clay Shrink Swell Building Damage Assessor, the broad flow of information they will be presented with, and information they must provide.

Attracting/redirecting potential users to the Clay Shrink Swell Building Damage Assessor

2DII is working with Lyon Place Financiere to publicise the Clay Shrink Swell Building Damage Assessor to homeowners in the City of Lyon to visit the Clay Shrink Swell Building Damage Assessor and estimate their potential financial risk. The community of Lyon Place Financiere is targeted at corporates rather than homeowners, however certain members could potentially be interested in the Clay Shrink Swell Building Damage Assessor and could help with publicising it. They are as follows:

- *Insurance:* Alexis Assurance, Allianz Trade, Apirl, Bibby, CFDP Assurance, Filhet Allard & Cie, Groupama, APICIL, MARSH, Metropolam
- *Residential:* CAPELLI, Habitat et Humanisme
- *Real estate:* JUNE REIM, JLL, Sogelym, Advenio
- *Research institute:* ISFA (cross-disciplinary training and research institute in actuarial and financial sciences, dedicated to the management of risks)
- *Institutions:* Métropole de Lyon, Bpifrance (Immobilier)

In addition, Lyon Place Financiere are in contact with local press organisations:

- Bref Eco
- Tribune de Lyon
- Journal des Entreprises
- La Tribune
- LE Progres
- Lyon Enterprises
- Lyon Decideurs
- Le Tout Lyon
- Les Echos



1: Landing page

Broad presentation	Specific details
Welcome page which presents information about what the Clay Shrink Swell Building Damage Assessor is intended to do and how it can help homeowners. Text needs to be visually stimulating and captivating to entice users to use the tool.	Explanation of CSS event, what causes them, how the phenomenon is connected to climate change and how it affects people. Alert that typical home insurance may not cover damage caused by CSS events. Explanation that the Clay Shrink Swell Building Damage Assessor is to educate homeowners on their risk and provide practical advice on what homeowners can do to protect themselves. At the bottom of the page will be a question as to whether the homeowner wants to find out more.

2: Broad articulation of the problem associated with CSS

Broad presentation	Specific details
Introduction to CSS and the issues at stake for homeowners. This information will synthesise information from this document and repackage this information in clear and transparent communication designed for a non-technical audience.	Explanation of the extent of property damage from CSS events. Illustration that the likelihood of CSS events occurring is projected to increase with climate change. Explanation of the weaknesses in the insurance framework (cat nat and multi-risk home insurance).

3: Users provide information for the Clay Shrink Swell Building Damage Assessor to calculate financial risk

Broad presentation	Specific details
Webpage where users insert information about their homes. Needs to be GDPR compliant and have appropriate limitations on use of data.	Users input information in relation to their property such as the address (to verify that the property is in a geographic area subject to CSS risk). Will have notice to ensure compliance with GDPR.

4: Presentation of financial (and other) risk metrics

Broad presentation	Specific details
Webpage where users are presented with information about their level of financial (and other) risks.	Presentation of various financial risk metrics in a way which is easily understandable for homeowners.

5: Suggested next steps for homeowners to protect themselves

Broad presentation	Specific details
Summary of next steps which homeowners can do to protect themselves.	PDF download of information in relation to various financial risk metrics and information for homeowners on steps they can take to reduce their risk.



4 Methodological and data aspects for Clay Shrink Swell Building Damage Assessor

This section articulates the methodological and data aspects which will be adopted by the Clay Shrink Swell Building Damage Assessor to support the user journey articulated in the previous section.

To support the user journey articulated in the previous section, the Clay Shrink Swell Building Damage Assessor will draw from the following data sources:

- *Research note on clay soil shrinkage and home insurance cover in France:* This will be synthesised to provide information in clear and transparent communication designed for a non-technical audience on the overall framework for home insurance in France and the gaps in this framework which cause risks for homeowners. Most of this research note is replicated in this document. *(Relevant for: 1: Landing page and 2: Broad articulation of the problem associated with CSS).*
- *Amigo:* PIISA consortium member Amigo will provide climate metrics which will be used to illustrate the likelihood of CSS events occurring is projected to increase with climate change. *(Relevant for: 2: Broad articulation of the problem associated with CSS).*
- *ERRIAL database:* This is an open-data website which will be used to verify that the property is in a geographic location which is susceptible to CSS risk. *(Relevant for: 2: Broad articulation of the problem associated with CSS).*
- *Explorateur de données foncières:* This is a public database that lists property sales and estimates a median price for properties in the cadastre sector *(Relevant for: 4: Presentation of financial (and other) risk metrics).*
- Third party research on cost of property damage as referenced later in this section. *(Relevant for: 4: Presentation of financial (and other) risk metrics)*

The following commentary describes the methodological approach and data sources for the key calculations in the user journey for the Clay Shrink Swell Building Damage Assessor.

At this stage we are not showing the specific text which will appear on each webpage – we are focussed solely on demonstrating how each verification or calculation step which appears in the Clay Shrink Swell Building Damage Assessor will be achieved. Please note further that *Annex 2 Specification for contracting* includes the contracting information which we will use to instruct a third party web developer to develop the Clay Shrink Swell Building Damage Assessor. Aspects such as the specific text which will appear on each web page will be under constant iteration alongside the user journey and interface design.

4.1 Climate factors: Illustrating that the likelihood of CSS events occurring is likely to increase with climate change

There is scientific consensus that climate change will cause an increase in longer and more severe heatwaves across the world as well as more intense and sporadic rainfall patterns (Slater et al., 2021). Studies have demonstrated the dependence of CSS events on climate and have confirmed the ability of drought to trigger subsidence (Harrison et al., 2012). These analyses were based on precipitation and air temperature data and recommended the use of land surface models (LSMs) as they provide more detailed information on droughts (Barthélémy et al., 2024). Both triggering factors for a CSS event (evapotranspiration and precipitation) are closely impacted by climate change and climate change projections imply an increased likelihood of CSS events in the future (Assadollahi, 2019).

Therefore the increased likelihood of a CSS event occurring can be illustrated using a proxy which relates to the increased likelihood of triggering factors such as drought, precipitation, heatwaves etc. occurring.

Barthélémy et al. (2024) analyse the metrics used to measure drought-linked CSS events. The paper focuses on the use of the Soil Wetness Index (**SWI**). It states that ‘several works focusing on subsidence in France have used the soil wetness index (SWI) outputs of the interactions between soil–biosphere–atmosphere (ISBA) land surface model (LSM; Noilhan and Planton, 1989; Noilhan and Mahfouf, 1996) developed by Météo-France, in a simplified configuration (monthly averages, homogeneous vegetation and soil). This product, called *SWI uniforme*, is also used for drought monitoring in the Cat Nat regime’ (Barthélémy et al., 2024). The Cat Nat regime recognises a CSS event if the affected area has at least 3% of its surface mapped as shrinkable clay and then looks at the meteorological conditions and identifies ‘exceptional periods of drought. Its current version requires the 3-month average of SWI uniforme to be the lowest or second lowest of a 50-year reference associated with the same month (Barthélémy et al., 2024).

The *SWI uniforme*, while useful, does not offer future projections, thereby limiting its predictive utility for future CSS events. Moreover, calculating SWI uniforme based on climate projections of soil water content could be time-consuming and complex, especially if the necessary data is not readily available or if the calculation involves complex processes that could require reliance on specific assumptions and/or parameterisations.

Given these considerations, 2DII decided to use climate data from the consortium partner Amigo for developing the Clay Shrink Swell Building Damage Assessor. Amigo proposes the use of a compound index that accounts for both temperature and precipitation data that is readily applicable to climate projections (further detailed below). The spatial resolution of this index is comparable to that of SWI uniforme (9 km vs. 8 km), potentially enabling comparisons between this compound index and SWI uniforme, if openly available. Moreover, the data required for

calculating the compound index (see Climate Dryness Index below) is more readily available compared to that for SWI uniforme. This has several advantages, especially data availability and therefore easier replicability in other cities and regions following the pilot in the City of Lyon.

The Climate Dryness Index

To assess the CSS phenomenon, Amigo proposes the development of a compound index called the Climate Dryness Index (**CDI**), which is designed to analyse the combined effect of drought and heatwaves on soil stability risk. The CDI incorporates two crucial aspects of extreme climate events: (1) the *intensity* of the event, which indicates whether an event is extreme or not; and (2) the *type* of event, through the contribution of each hazard indicator to the overall intensity of the index.

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. Given that drought is the primary trigger for CSS events, and this can be exacerbated by the simultaneous occurrence of heatwaves, calculating using climate projections based on both SPI and SHI on climate projections will provide a comprehensive view of the future climatic conditions that can lead to CSS events, which are essential to give the user of the dashboard some insight into how the risk may evolve in the future.

The CDI is designed to include the two different components (climatological variables) into a single index and is based on the procedure for obtaining multi-hazard indices developed for the Extreme Climate Facility (**XCF**) proposed by the African Risk Capacity (**ARC**) (African Risk Capacity, 2017). Assuming each single-hazard index has a standard normal distribution (as in the case of SPI and SHI), it is thus intuitive to mathematically define CDI as the sum of squares of these indices, which yields in turn, a standardised index. To reduce the effect of inter-correlation between the single-hazard indexes, correlation coefficients will be used as weighting parameters of such indices.

The CDI approach is flexible and can be easily adapted to different regions and time scales. It also enables the inclusion of additional hazard indicators if needed, ensuring scalability and adaptability to various contexts.

By using the CDI, we can separately analyse the impacts of precipitation deficits (drought) and extreme temperatures (heatwaves). This enables to clearly identify and understand the individual contributions of these two primary factors influencing CSS events, as well as their combined

effect. While Standardized Precipitation Evapotranspiration Index (**SPEI**) combines both precipitation and potential evapotranspiration, it may obscure the distinct effects of drought and heatwaves. However, we do not exclude using it in a subsequent study for comparison.

Data

SPI and SHI will be 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). 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 spatial resolution of climate model outputs. This enables to increase the resolution of the raw data from the original grid (100-250 km) to 0.1° (about 9 km). The employed bias correction algorithm extends the methodology for seasonal forecasts outlined in Trentini et al. (2023) making it applicable to climate projections.

A preliminary literature review to select the best CMIP6 model for describing future CSS trends revealed that MPI-ESM1-2 and EC-Earth3 are mentioned among the best-performing models for temperature and precipitation prediction (Xu et al., 2023, Nguyen-Duy et al., 2023, Patel et al., 2023). For this reason, an initial version of the CDI will be developed using one of these two models. Further work will consider multiple climate models with varying resolutions to obtain a comprehensive understanding of the trends in extreme events and a more complete representation of the uncertainty. A multi-model ensemble approach helps to account for the strengths and weaknesses of each model and provides a more robust analysis of the changes in extreme weather phenomena. This approach will enable us to better assess the risk of CSS events under different climate scenarios and improve the reliability of our predictions.

Methodology

To illustrate the increased likelihood of a CSS event in the future, we will look for the likelihood of an increase in droughts where CDI is the lowest or second lowest in a 50-year reference. The French Cat Nat scheme uses a 3-month average, but with such a threshold, some cases are omitted. Since we are creating an informational dashboard, we have chosen a 2-month average to include as many cases as possible to inform users of the potential risk increase in the future. The increased likelihood will be calculated for different yearly time windows comprising the next 5, 10, 15, 20, and 25 years.

The choice of a 50-year reference is consistent with the Cat Nat definition of a CSS event, which requires the 3-month average of SWI uniforme to be the lowest or second lowest of a 50-year reference associated with the same month. However, we might consider different reference periods and include a study of the likelihood of CSS events over a historical baseline for comparison.

The presentation of the data on the Clay Shrink Swell Building Damage Assessor will be both textual and graphical to ensure clarity and ease of understanding. For instance, the likelihood of

increased heatwave and drought conditions will be presented both as a percentage in text form and through graphical and intuitive illustrations such as bar plots, bee swarm charts etc. Bee swarm charts are a visualisation technique to examine the change in frequency of extreme events. These plots can be used to analyse extreme weather phenomena, including heatwaves and drought. By tracking extreme temperature values over time, it is possible to identify changes in the frequency, intensity, and duration of these events, which are critical indicators of climate change.



4.2 Local factors: Verifying that the property is in a geographic area subject to CSS risk

As referred to in *Section 1.1 Clay shrink swell in France*, it is estimated that 48% of the national territory is at medium or high risk of CSS event or in other words 10.4 million single-family homes are at medium or high risk of a CSS event, representing 54% of all single-family homes (Sénat, 2023).

In the last two decades, the number of CSS events has increased in France and the French Government (an initiative of the French Ministry of Ecological Transition in collaboration with the Geological and Mining Research Bureau (BRGM)) has created an open-data tool called ERRIAL, which allows its users to see the risks they may face according to the location they input.

The Clay Shrink Swell Building Damage Assessor will use the data contained within the ERRIAL tool which will enable the Clay Shrink Swell Building Damage Assessor to show the level of CSS risk according to geographic location of the homeowner's property. We consider that the ERRIAL tool is an authoritative and credible data source to provide an illustration of the level of CSS risk. Other potentially relevant metrics which relate to local factors (e.g. vegetation growth or incline of the ground) are not covered by the Clay Shrink Swell Building Damage Assessor, except those that are already integrated into the ERRIAL tool (e.g. soil topography). This decision was taken in view of the guiding parameters for the development process of the Clay Shrink Swell Building Damage Assessor (e.g. simplicity, clarity of communication etc.) as set out in *Section 2 Objectives for the Clay Shrink Swell Building Damage Assessor*. By way of illustration we consider that asking homeowners to insert data on vegetation growth or incline of the ground is not information a non-technical audience will be able to provide – therefore requesting this information will dissuade users from using the Clay Shrink Swell Building Damage Assessor (and/or may lead to inaccurate information being inserted by the user).

The ERRIAL tool geolocates CSS risks and distinguishes between three levels of risk: Low, Medium, and High. As you can see from *Figure 3* and *Figure 4* below, the level of CSS risk in Lyon varies between Low in the very centre of the city to Medium in the surrounding areas.



Figure 3: Centre of Lyon exposure to CSS



Figure 4: Northwest of Lyon and its suburbs exposure to CSS

The ERRIAL tool functions as an open tool that combines different types of data to measure property risk. The ERRIAL tool assesses areas with varying seismicity levels, soil contamination, radon potential as well as other information such as coastal line recession or airport noise exposure. The objective of ERRIAL tool is to provide property owners with a source of information when creating their property's risk plan. The owner, using their address or parcel



number, can identify the risks that may affect the property. Subsequently, the owner must verify the accuracy of the information or complete the document with information available from the prefecture. Finally, the owner will obtain the documentation required on the risk plan.

In this context, it uses information from the cadastral plan, the database of former industrial sites (BASIS), data on contaminated lands and soils, data on ground movement, data on flood risk areas, data on natural and technological risk prevention plans, and other data related to natural and technological risks and nuisances. Although the ERRIAL tool is designed to make it easier for property owners and lawyers to meet the risk plan requirement and expedite property sales, for the purposes of the Clay Shrink Swell Building Damage Assessor it can provide reliable and relevant information about the different types of risks to which a property is exposed, and thus to combine various information on the Clay Shrink Swell Building Damage Assessor.

Following the law of open/license of the French Government, the data in ERRIAL is public and has free re-use rights. In the case of the Application Programming Interface (API) (see below), the information is in the following links:

- Ministère de la Transition écologique. (n.d.). Guide de l'aménagement et du cadastre. <https://api.gouv.fr/guides/amenagement-cadastre>
- Ministère de la Transition écologique. (n.d.). API GéoRisques. <https://api.gouv.fr/les-api/api-georisques#quels-sont-les-types-de-donnees-renvoyees-par-l-api-georisques>
- Open-source legal information:
 - Ministère de la Transition écologique et de la Cohésion des territoires. (n.d.). Mentions légales. <https://www.georisques.gouv.fr/mentions-legales>
 - Etalab. (2014). Licence Ouverte. https://www.etalab.gouv.fr/wp-content/uploads/2014/05/Licence_Ouverte.pdf

The following steps will be used to integrate ERRIAL data into the Clay Shrink Swell Building Damage Assessor:

1. Data extraction: Use the API (Application Programming Interface) to fetch the data.
2. Data transformation: Convert the data into the format required by the Clay Shrink Swell Building Damage Assessor and remove unnecessary information.
3. Direct integration: Involve the real-time API calls.
4. Visualisation: Design the interface to be user-friendly.

Therefore, the Clay Shrink Swell Building Damage Assessor will use the API of ERRIAL, which has several benefits. These include accessing the latest information, automating data updates, ensuring data certification at the source, and eliminating the need to download and store files and data sets. From the user's perspective, they will only need to enter their address or parcel number to access the information, thereby simplifying information retrieval.

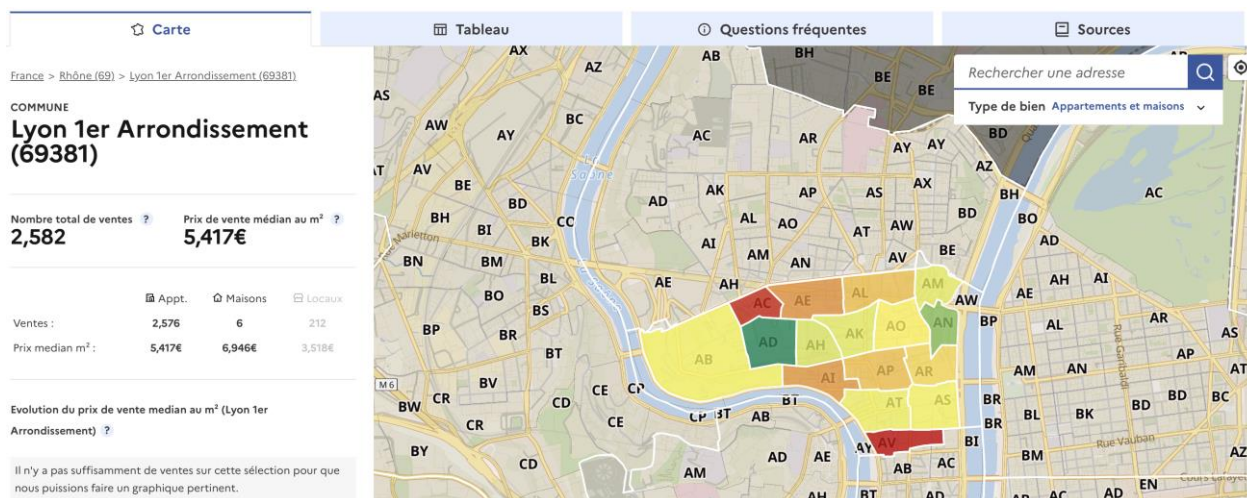
4.3 Estimating the value of the property

In France, Land Data Explorer (*Explorateur de données foncières*) (Ministère de la Transition écologique, Undated) is a public database that lists property sales and estimates 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).

The information is available in the following links:

- <https://api.gouv.fr/les-api/api-donnees-foncieres>
- <https://explore.data.gouv.fr/fr/immobilier?onglet=tableau&filtre=tous&lat=45.43063&lng=5.35158&zoom=6.45>

This contains information on real estate sales, which will allow us to estimate the property value. The files capture information such as the sale price, address, date of transfer (currently between 1 January 2014 and 30 June 2023, pending the updating of new property transactions), cadastral information, property size, land use and more.



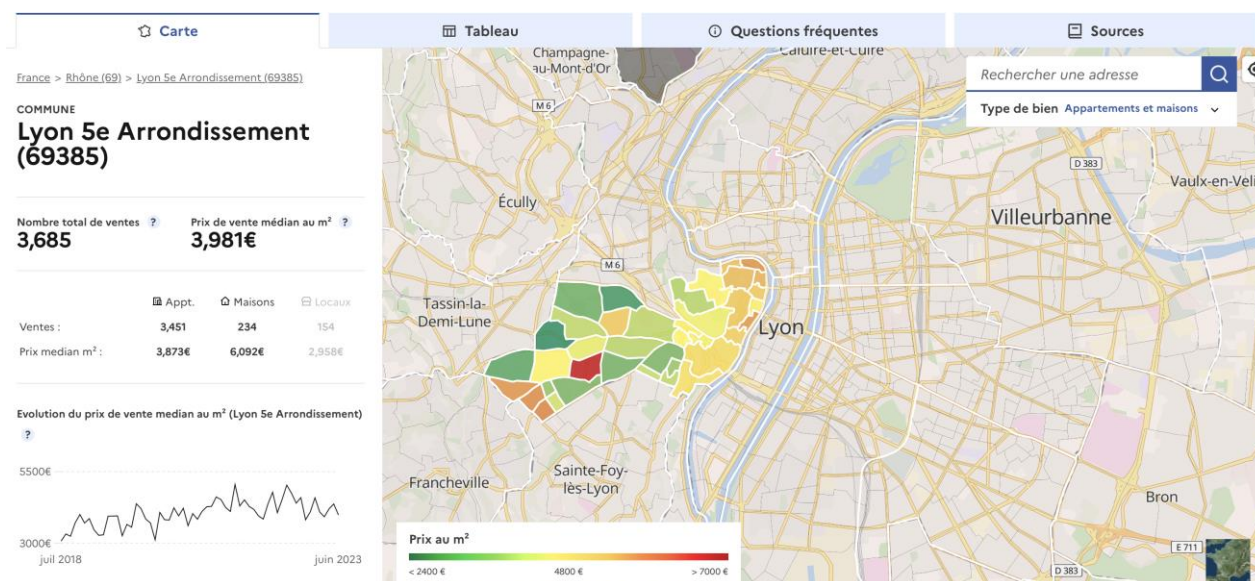


Figure 5: Land Data Explorer for the City of Lyon

Using the information in the DVF, the sale price for the property and the average price per square meter for the cadastral area will be obtained. The Clay Shrink Swell Building Damage Assessor will estimate the property value as:

- Where the last sale of the property occurred within the last three years, the property value will be estimated as the last sale price of the property.
- Where the last sale of the property is more than three years ago, or there is no sale price available, the property value will be estimated using the average price per square meter in the cadastral area multiplied by the floor area for the property. Thus, we will estimate the property price using the average price per square meter (the average price per square meter will be calculated using the variables of the financial value of the sale divided by surface, then within the cadastral area, we will estimate the average using the available data information) within the cadastral area, and subsequently, the user will be asked for the size of their property, to obtain the missing data information.

The DVF database is public and freely available. To extract the information, we will download the information for the City of Lyon, organise it in a format compatible with the Clay Shrink Swell Building Damage Assessor software and integrate all the information. The database ID, which in this case is the address and the “parcelle” code, will allow us to merge this data with the other sources on the Clay Shrink Swell Building Damage Assessor, and then, the user with their address will access the information (see *Section 4.5 User experience*).

4.4 Financial risk metrics: Empirical data on cost of damages

Financial Risk Metric 1: Average cost of repairs for property damage

A report from France's National Assembly found that the cost of repairs for property damage caused by a CSS event could range from €1,000 to €100,000 (see Figure 6 below). The research analysed the average insurance payouts to reimburse the homeowner for the cost of repairs to property damage caused by a CSS event that had been recognised under the Cat Nat scheme. Therefore, while these figures do relate to insurance payouts for damage caused by a CSS event, it must be noted that over the last nine years, an average of 50% of requests for official recognition of a CSS event as a natural catastrophe under the Cat Nat scheme have been unsuccessful (see *Section 1.5 Potential insurance risks for homeowners*).

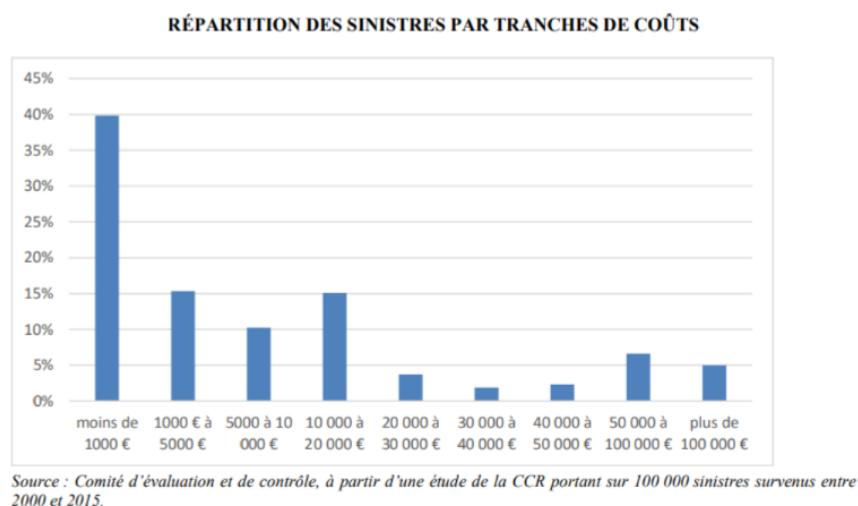


Figure 6: Average cost of repairs for CSS events in France between 2000 and 2015 (Assemblée Nationale, 2023)

According to Figure 6 the cost of repairs is commonly between €10,000 and €20,000. Pay-outs under €1000 can be excluded because they usually represent expert costs to determine if the property damage was caused by a CSS event. In 68% of cases, the cost of repairs was under €20,000 (Assemblée Nationale, 2023). However, it is important to note that repairs in this price range are typically regarded as quick fixes meaning that the property repairs are superficial and may not solve the problem in the long term (therefore possibly leaving the property exposed to further damage from CSS events in the future. More effective and durable solutions are correspondingly more expensive and cost upwards of €50,000 to install.

Homeowners therefore have two choices when it comes to property repairs - a quick low-cost repair which will potentially not secure the property against future damage from CSS events, and expensive but more durable repairs. This choice is clearly noticeable in Figure 6 since pay-outs ranging between €20,000 and €50,000 represent a minimal portion of the sample. As the

insurance will cover damages up to the value of the house, this may mean that the homeowner can implement the more effective solution, but this may not be possible in all cases.

The complexity here is that the extent of repairs will vary according to the extent of damage which can vary between slight cracks in a wall to serious structural damage. As highlighted in a real-case example, in the summer of 2022 four houses in the same street were affected by CSS and all of them needed to be supported both inside and outside at an individual cost of €60,000. However, the four houses are covered by four different insurers and four different insurance experts. These experts did not coordinate, which delayed the handling of the situation. This can be explained as steps involved in assessing and managing the damage are not standardised among the professionals (insurers, expertise firms), complicating the process. Thus the four insurers deciding on different ways to take care of the issue: two insurers decided on demolition and reconstruction, the other two proposed structural reinforcement (Ministère de l'Intérieur et des Outre-mer, 2023).

In view of these considerations we will present metrics for the average cost of repairs based on the third-party research referred to above. We will work with the interface designer during the software development stage to develop an appealing visual to present this information. A likely route forward here is to present the average cost of repairs as an estimated range from a minimum to a maximum value (for example a colour spectrum according to CSS severity: light damage = yellow (repairs < 15k); medium damage = orange (repairs < 30k); severe damage = red (repairs > 30k) while noting that the theoretical limit for property damage under the insurance policy is the full cost of the property. In addition this information could be explained relative to typical economic statistics such as annual savings (for the poorest 20%, average annual savings are €357, for the French middle, average annual savings are €2,520 and for the richest 20%, average annual savings are €15,931).

Financial Risk Metric 2: Full value of the property

It is not possible to derive an equation to model the relationship on how property damage caused by a CSS event impacts on the value of the property. As set out above, the damage can vary between slight cracks in a wall to serious structural damage (and the cost of repairs will correspondingly vary) and there are numerous variables which would determine how this impacts on the property value. Reductions in property value are not typically covered by insurance policies in general. If damage from a CSS event makes the property less valuable, the insurance will not usually provide compensation.

However, the insurance payouts for losses resulting from property damage caused by a CSS event is capped at the value of the insured property at the time of the loss (assuming that the CSS event is recognised by the State as a natural catastrophe). And as set out in the real case example above, demolition can occur in certain circumstances. Therefore, it is theoretically possible that the property damage is so severe that demolition is recommended while the CSS event is not recognised under the Cat Nat mechanism meaning that the homeowner is not insured. In any case the property is likely to be one of the homeowner's most significant asset

and the occurrence of property damage caused by a CSS event will impact on the homeowner's ability to sell the property as this information must be disclosed to a buyer. Sellers have a duty to disclose property damage from a CSS event when selling a property in application of Article 125-5 Code de l'environnement

And at the same time, the property value can be a useful comparator for illustrating the size of the financial risk compared to the value of the asset. For example, if a property is valued at €266,000 (Logic Immo, 2022) and is located in a very at-risk area where repairs could climb to €60,000, the homeowner will understand that repairs could end up costing close to a fifth of the property's value.

In view of these considerations we will present a metric which relates to the property value (as estimated according to *Section 4.3 Estimating the value of the property*). We will work with the interface designer during the software development stage to develop an appealing visual to present this information. However this is likely to include explanatory text to contextualise the metric. For example:

- Your property is valued at ***. If you suffer property damage from a CSS event and a Cat Nat is recognised by the State then your insurance cover is up to the value of your property – but if a Cat Nat is not recognised by the State you have no cover.
- Property damage from a CSS event must be disclosed to a buyer when you sell your property. This can make selling your property much harder and is likely to reduce the sale price – which is a big obstacle for your most substantial asset.

We will also consider including an estimated variable called "adjusted price of the property" which will indicate that if no preventative measures are taken, the likely sale price will start to depreciate. We will take the current price and deduct *Financial Risk Metric 1: Average cost of repairs for property damage*, assuming there is no appreciation in the area.

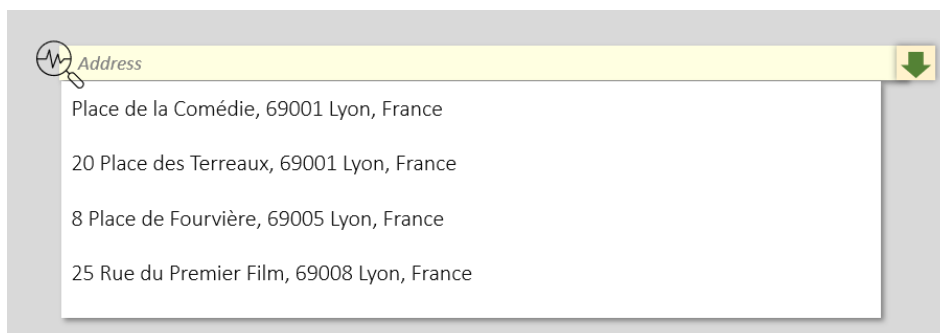
NOTE: In some reported cases (Ministère de l'Intérieur et des Outre-mer, 2023), homeowners who have suffered severe property damage were unable to move because the insurance would not cover alternative accommodation. This meant that the family had to remain in their damaged house, suffering from strong drafts, persistent fear and much higher heating bills. We might refer to this being a remote possibility in severe cases, but calculating the average cost of alternative accommodation is an unnecessary option and would just overcomplicate the Clay Shrink Swell Building Damage Assessor.

4.5 User experience

This section provides an initial mock up indication of key parts of the user experience in relation to 3: *Users provide information for the Clay Shrink Swell Building Damage Assessor to calculate financial risk*, 4: *Presentation of financial (and other) risk metrics* and 5: *Suggested next steps for homeowners to protect themselves*. As referred to elsewhere in this document, the Clay Shrink Swell Building Damage Assessor will be designed to be intuitive, informative and visually engaging.



A key step will be for homeowners to insert their address on the webpage corresponding to 3: *Users provide information for the Clay Shrink Swell Building Damage Assessor to calculate financial risk.*



Address

- Place de la Comédie, 69001 Lyon, France
- 20 Place des Terreaux, 69001 Lyon, France
- 8 Place de Fourvière, 69005 Lyon, France
- 25 Rue du Premier Film, 69008 Lyon, France

Figure 7: Example of how the user could be asked to insert their address

After homeowners have inserted the required information for the Clay Shrink Swell Building Damage Assessor, the webpage corresponding to 4: *Presentation of financial (and other) risk metrics* will present various information including:

- Likelihood of CSS event increasing in future
- Risk level for the location of the property
- Financial Risk Metric 1: Average cost of repairs for property damage
- Financial Risk Metric 2: Full value of the property

This information will all be available within the same webpage. The third-party databases which the Clay Shrink Swell Building Damage Assessor will interface with use the same ID-parcelle, which will be the common variable to generate the merge between them. Besides, both databases contain the geo-referenced coordinates, allowing the Clay Shrink Swell Building Damage Assessor to show the localisation.

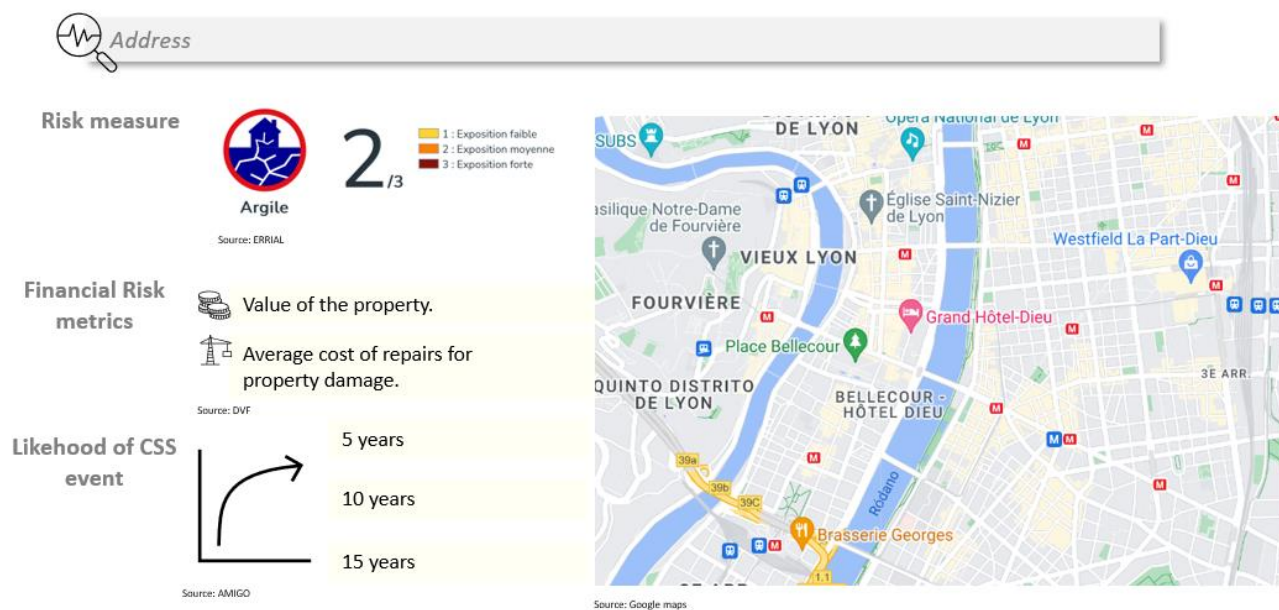


Figure 8: Example of how the financial (and other) risk metrics could be presented

Finally, the webpage corresponding to 5: *Suggested next steps for homeowners to protect themselves* will enable the homeowner to generate and download a PDF with this information on risks and information on next steps the homeowner can do to reduce the risk.

5 Guidance for homeowners to protect themselves

This section articulates measures which homeowners can follow to reduce the risk associated with inadequate insurance cover for property damage caused by CSS events. This information will be synthesised in a way which can be easily understood for homeowners and included in the PDF which will be available for download from the Clay Shrink Swell Building Damage Assessor.

5.1 Ask the right questions before buying a property

Before purchasing a property, buyers should inquire whether the city has a Natural Risk Prevention Plan (PPRN) (e.g. by checking the website of the local municipality) and verify if the property or buildable land is subject to CSS risk on the GeoRisk website.

Buyers should ensure that all preventive measures articulated in the PPRN have been implemented, both during and after construction of the property.

5.2 Ensure preventive measures are carried out

To ensure preventive measures are carried out, it is advisable to consult technical specialists to determine the extent of the necessary work and to carry it out effectively. It is also recommended to document all the preventive measures taken, as the insurance company may require proof of these measures when reviewing an insurance claim.

Non mandatory preventive measures

Homeowners can always carry out additional preventative measures to those articulated in the PPRN. In these circumstances, there are two categories of preventive measures:

- *Vertical measures* are those which relate specifically to the property to prevent CSS. They are very effective but expensive and cost between €21,000 to €76,000.
- *Horizontal measures* involve acting on the surrounding environment to prevent soil movement (for example, the installation of anti-root screens or drainage systems). While their effectiveness is not perfect they are less invasive than vertical measures and cost an average of €10,000 (Sénat, 2023).

When deciding upon preventive measures, homeowners need to make an informed choice regarding their effectiveness and cost and the surrounding area of the property.

Financing preventive measures

Implementing the preventive measures can be expensive for homeowners therefore there is an important question in relation to state support. In particular, the *Fonds de Prévention des Risques Naturels Majeurs* (FPRNM) would help homeowners cover the cost of the preventive measures.

The FPRNM (established under Act 95-101 of 2 February 1995 to strengthen environmental protection and commonly known as the Fonds Barnier) is linked to the Cat Nat scheme and

serves as a vital resource for the prevention of major natural risks through playing a crucial role in funding a wide range of preventive measures outlined in PPRN, both mandatory and non-mandatory. Allocation of funds from the FPRNM is based on a collaborative decision-making process involving the Mayor and property owners, with the ultimate determination made by the State (Sénat, 2023).

One key aspect of the FPRNM is its support for initiatives aimed at reducing the vulnerability of private properties, including homes and small businesses, under specific conditions. However, it is important to note that the fund's scope is focused primarily on addressing risks that directly impact human life.

Currently, there is ongoing discussion regarding whether the FPRNM should cover CSS. The Directorate-General for Risk Prevention (**DGPR**) has highlighted the distinct characteristics of CSS compared to other risks covered by the fund, noting that it may not meet the criteria of a major natural hazard directly impacting human life. Indeed, according to the DGPR, CSS has different characteristics from other risks covered by the fund: 'clay soil shrinkage is not considered a major natural hazard in the sense that it does not have a direct impact on human life, which is essentially the philosophy behind the FPRNM' (Sénat, 2023).

Therefore, at present there is significant uncertainty as to whether the FPRNM can be accessed to provide financial support to implement preventative measures. If the FPRNM does not cover CSS, the homeowner would need to cover the costs of implementing the preventative measure themselves.

5.3 Participate in political action

Lobby representative

Homeowners can lobby their representative for measures to alleviate the risks arising from property damage caused by a CSS event. For example, a better mitigation plan to reduce the likelihood of property damage from CSS or an easier and more accessible funding scheme to implement preventive measures.

Engage associations

Homeowners can engage or participate in associations to raise public awareness of the issue and advocate for better rights and protection for homeowners. Being part of an association can also be helpful to be aware of and understand all the steps and protections that are available for homeowners.

The national association: *Les oubliés de la canicule* which aims to increase awareness of the drought phenomenon and its effects, the drought hazard map, and parameters for assessing sensitive soil. This association also aims to provide complementary information to legal institutions (local authorities, insurers etc.) and to support homeowners through providing information and advice on the main repair techniques and the choice of repair companies. The



association has launched two petitions (one to the President of the Republic and one to the Minister of the Interior) asking for a better indemnification of CSS.

The *Association française pour la prévention des catastrophes naturelles et technologiques* aims to create a permanent, cross-disciplinary, multi-hazard platform of players (legal entities and individuals) involved in preventing and managing disaster risks and reducing their consequences.

The *Association Nationale des Assurés Sinistrés Sécheresse* aims to help and assist with administrative procedures for policyholders who are victims of drought affecting their property, and more generally support them in following procedures aimed at compensation of their claim.

There are also local associations which are generally listed in the city website, such as *Association Ardéchoise des Sinistrés de l'Ardèche – CatNat*. They do not have a website, but they organise meetings and pressure at local level for the recognition of the state of Cat Nat.

5.4 Request a specific endorsement in the home insurance policy

Homeowners could in theory request that insurers include a clause in their insurance contracts that covers property damage from a CSS event even when a natural catastrophe has not been recognised by the State. While there is no established practice for this yet, it is conceivable that if enough property owners make this demand, it could potentially lead to a change. However, it is important to note that this would entail significant additional costs for insurance companies and consequently for homeowners.



6 Roadmap for next steps

Based on the work and insights generated so far to inform this document, we consider that after the initial pilot in the City of Lyon, the next steps (e.g. during Loop 3 as per the Grant Agreement) should primarily focus on replicating the tool in other cities or regions in France.

There are various reasons for this position, but the two principal reasons are:

- The Clay Shrink Swell Building Damage Assessor will synthesise information about the French state catastrophe naturelle framework and how this state framework working with commercial home insurance cover may leave gaps in insurance cover for French homeowners. This information is French specific and shapes a lot of the user journey and the provision of information which is planned for the Clay Shrink Swell Building Damage Assessor. However the insurance framework which applies in other Member States is likely to be different.
- The Clay Shrink Swell Building Damage Assessor will draw information from French public databases as well as French specific climate projections from Amigo. Replicating the tool in other countries will require other public databases to be available in the relevant country OR different methodological assumptions – both of which will be time intensive and costly.

More importantly, replicating the Clay Shrink Swell Building Damage Assessor for other cities or regions in France would enable the PIISA consortium to really establish the proof of concept and the Clay Shrink Swell Building Damage Assessor as a significant resource tool of reference, which is well publicised and effective in exerting leverage on the insurance industry in France. This is a much more efficient and effective use of consortium resources (in terms of work activities and costs). The alternative of simply doing an initial pilot in the City of Lyon and then immediately trying to do replicate in a very different location runs the risk of trying to replicate something which is not yet well established in France and is a much less efficient and effective use of consortium resources (in terms of work activities and costs).

However, in view of broader replicability aspects and securing legacy of the PIISA project, Loop 3 will also include research and outreach to publicise and ideally create demand for replication of the Clay Shrink Swell Building Damage Assessor in other EU countries. This will include:

- Researching CSS risk level and insurance framework for other EU countries to identify likely demand for replication of the Clay Shrink Swell Building Damage Assessor (potentially with AXA, BSC, FMI and other PIISA consortium members);
- Outreach to consumer organisations and other stakeholders (e.g. local authorities, environmental bureaux etc.) in hotspot risk areas to publicise and create demand for replication of the Clay Shrink Swell Building Damage Assessor in that area;
- Interfacing with the (renamed) PIISA Adaptation and Insurance Market Radar/PIISA Adaptation and Insurance Knowledge HUB to publicise the tool.



We will use a roadmap as a strategic planning tool to define goals and major steps to reach them. It is important to understand that the roadmap is a strategic document (rather than a fixed document that captures all details) and a tool to coherently organise project resources to define and reach the goals for the Clay Shrink Swell Building Damage Assessor and contribute to the overall aims of the PIISA project.

Figure 9 articulates a first version of the roadmap for future work activities under Loop 2 and Loop 3 which reflects this dual focus of: (1) replicating the Clay Shrink Swell Building Damage Assessor itself in other cities and regions in France; and (2) further work and activities to publicise and ideally create demand for replication of the Clay Shrink Swell Building Damage Assessor in other EU countries.

	PIISA Loop 1 (M6-M19)	PIISA Loop 2 (M19-M25)	PIISA Loop 3 (M25-M33) (including PIISA Final Sprint)	PIISA Legacy
Tool development	1. Research Cat Nat and insurance framework in France. 2. Research information available in public databases in France. 3. Develop methodology which will underpin the Clay Shrink Swell Building Damage Assessor. 4. Develop specification for contracting web developer. 5. Contract web developer. 6. Develop prototype of Clay Shrink Swell Building Damage Assessor. 7. Internal testing.	1. Launch Clay Shrink Swell Building Damage Assessor in City of Lyon. 2. Testing.	1. Replicate Clay Shrink Swell Building Damage Assessor in other cities and regions in France (including English version).	1. Hosting, maintenance and development is solved.
Piloting	1. Develop Roadmap. 2. Feedback survey.	1. Test user feedback/feedback survey. 2. Iterate Clay Shrink Swell Building Damage Assessor to address user feedback.	1. Test user feedback/feedback survey. 2. Assess and address to the extent possible user feedback.	1. More EU countries develop national versions of Clay Shrink Swell Building Damage Assessor.
Upscaling	1. Publicise Clay Shrink Swell Building Damage Assessor in City of Lyon.	1. Identify other cities and regions in France for replication of Clay Shrink Swell Building Damage Assessor in Loop 3. 2. Research CSS risk level and insurance framework for other EU countries to identify likely demand for replication Clay Shrink	1. Webinar and workshop. 2. Conduct outreach as per Outreach Plan developed in Loop 2. 3. Interface with the PIISA Adaptation and Insurance Market Radar/PIISA Adaptation and Insurance Knowledge HUB.	1. Recognised tool for homeowners to assess risks.

		Swell Building Damage Assessor. 3. Assess and identify third party stakeholders (e.g. insurance community, consumer protection organisations etc.). 4. Develop detailed Outreach Plan for Loop 3.	4. Guidance and interpretation requirements for replication of Clay Shrink Swell Building Damage Assessor in other EU countries.	
GA Deliverable		D3.6/Lessons learned from testing usage in Lyon, France/WP3/9-2DII/R – Document, report/PU – Public/M25	Included in: D3.11/Pilots for Cities and well-being/WP3/9-2DII/R – Document, report/PU – Public/M33 Included in: D3.14/Measures to amplify use of insurance solutions to support adaptation/WP3/1 – FMI/R – Document, report/PU – Public/M34 Included in: D3.2/Summary of lessons learned/WP3 1 – FMI/R – Document, report/PU – Public/M33	

Figure 9: Roadmap for future work with the Clay Shrink Swell Building Damage Assessor

This first version of the roadmap can be used in communication with the whole PIISA consortium to align them on one strategy and in communication with stakeholders to engage them to obtain a desired outcome. The roadmap will be updated based on the progress of piloting, and a revised version of the roadmap will be introduced in Deliverable 3.6 “Lessons learned from testing usage in Lyon, France”.

As PIISA’s ambitious aims include creating a systemic impact to advance adaptation to climate change, the timeline covered by the roadmap includes aspects of the PIISA Legacy, which will be developed in collaboration with relevant stakeholders.

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Legislation

Code civil, article L1792-4-1

Code de l'environnement, article L125-5

Code des assurance, article L125-1

Code des assurance, article L125-2

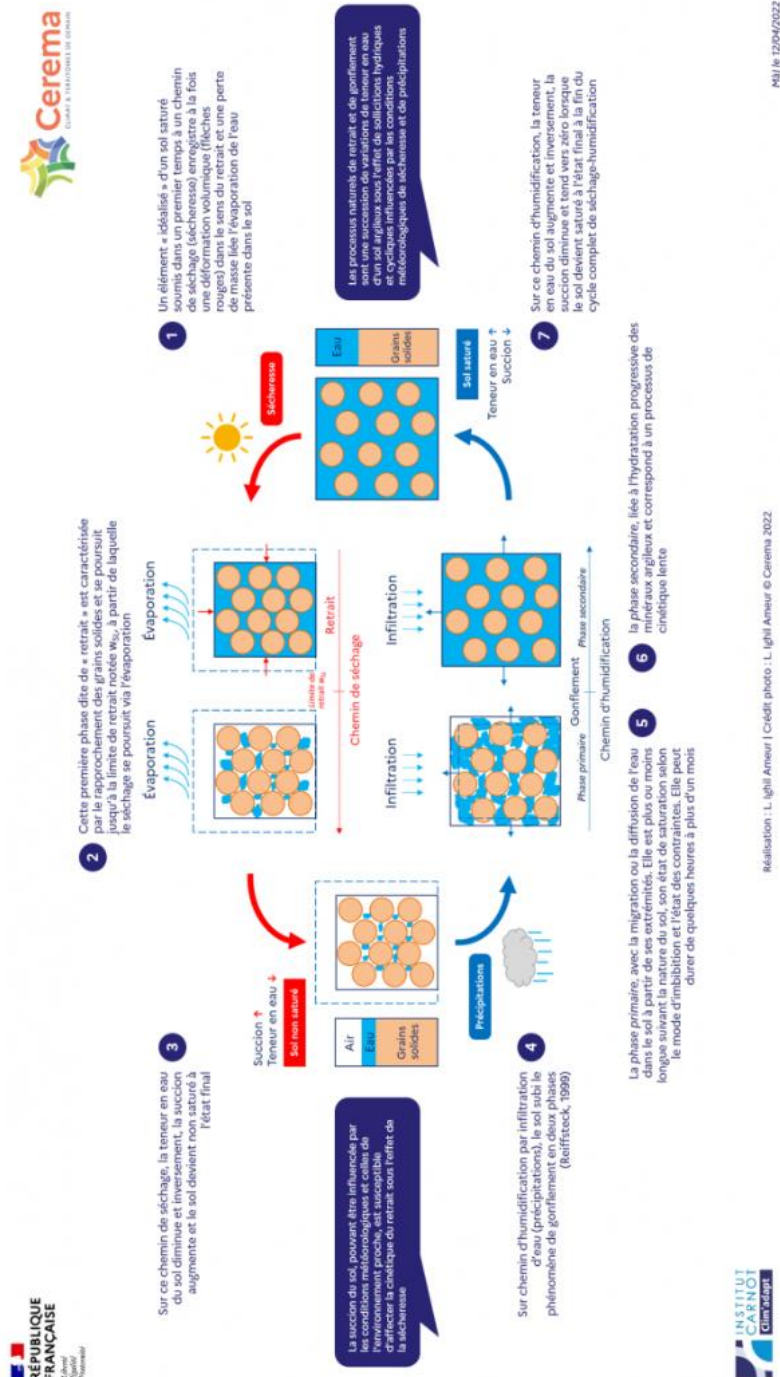
Code des assurance, article L125-3

Code des assurance, article L125-4

Loi n° 2018-1021 du 23 novembre 2018 portant évolution du logement, de l'aménagement et du numérique



Annex 1 Causative factors for a CSS event



Maj le 12/04/2022

Réalisation : L. Ighil Aineur | Crédit photo : L. Ighil Aineur © Cerema 2022

Translation

1. An "idealized" element of saturated soil initially subjected to a drying path (drought) experiences both volumetric deformation (red arrows) due to shrinkage and a loss of mass linked to the evaporation of water present in the soil.
 2. This first drying phase is characterized by mass loss as the water evaporates. The level of shrinkage depends on the suction generated by the evaporation.
 3. During the drying path, the suction increases as the amount of water decreases, which leads to soil shrinkage. The soil deforms due to the increased suction, becoming less saturated.
 4. On the path of humidification by water infiltration (precipitation), the soil undergoes the swelling phenomenon in two phases (Reiffsteck, 1999).
 5. The primary humidification phase, involving water infiltration, leads to a slow re-saturation of the soil, which may take several weeks to months.
 6. The secondary phase, corresponding to progressive soil hydration, marks the end of the drying/humidification cycle. This phase represents complete soil rehydration.
- Left - blue bubble: Soil suction, which can be influenced by meteorological conditions and those of the nearby environment, is likely to affect the kinetics of shrinkage under the effect of drought.
 - Right - blue bubble: The natural processes of shrinkage and swelling are a succession of variations in the water content of clayey soil under the effect of hydraulic and cyclic stresses, influenced by meteorological conditions of drought and precipitation.

Words used to explain the flow

Air: Air Chemin d'humidification: Humidification path Chemin de séchage: Drying path Eau: Water Évaporation: evaporation Gonflement: Swelling Grains solides: Solid particles (or solid grains) Infiltration: Infiltration	Limite de retrait: specific moisture threshold below which no further shrinkage occurs. Phase primaire: Primary phase Phase secondaire: Secondary phase Retrait: overall process of shrinking Sol non saturé: Unsaturated soil Succion: Suction Teneur en eau: Water content
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Annex 2 Specification for contracting

2° Investing Initiative is looking for a web developer to lead the design, development and implementation of the Clay Shrink Swell Building Damage Assessor described in the document: *[D3.5 Preliminary dashboard specification]*. This work is likely to involve a web developer, who will be responsible for all the technical aspects of the project and a web designer who will support the develop the overall architecture and user interface of the Clay Shrink Swell Building Damage Assessor.

Scope of work

Lead the design, development and implementation of the Clay Shrink Swell Building Damage Assessor. Key responsibilities include:

- **Data integration:** Integrate or interface with the different datasets mentioned in Section 4 of the document: *[D3.5 Preliminary dashboard specification]*.
- **Design and development:** Design the overall architecture and user interface of the Clay Shrink Swell Building Damage Assessor, focusing on intuitive navigation and accessibility.
- **Develop the frontend and backend components.** The frontend is required to be responsive (compatible with phone and tablet screens).
- Develop a component that will generate a PDF, based on the user's search results.
- Implement Google Analytics tracking to measure the principal usage of the website (number of page views, pdf generated etc.).
- **Visualization tools:** Implement data visualization tools and techniques to represent the indicators (as referred to in Section 4 of the document: *[D3.5 Preliminary dashboard specification]* including maps, charts and graphs).
- Develop the autocomplete feature for homeowner to input the property addresses.
- **User Authentication and Security:** Develop secure user authentication and authorization mechanisms to protect sensitive data and ensure user privacy.
- Implement best practices for web security.
- **Testing and Quality Assurance:** Conduct thorough testing, including unit tests, integration tests and user acceptance testing to ensure that the Clay Shrink Swell Building Damage Assessor is bug-free and meets all requirements.
- **Deployment and Maintenance:** Oversee the deployment of the Clay Shrink Swell Building Damage Assessor on a reliable hosting platform. Provide ongoing maintenance and updates to accommodate new data sources, user feedback, and emerging needs.
- **Documentation and Training:** Create comprehensive documentation, including technical documentation for future developers and user guides for end-users. Provide training sessions if necessary.
- **Minimum Viable Product (MVP)** only for the city of Lyon, France.



Please note that the Clay Shrink Swell Building Damage Assessor will be pilot tested in the City of Lyon, however in subsequent stages of the project the Clay Shrink Swell Building Damage Assessor will be replicated in other cities and regions in France.

Timescales

The Clay Shrink Swell Building Damage Assessor must be available and bug-free for the end of 2024.

Costs

Infrastructure: Servers Between 500 – 1000 per year

Domain name: 50 per year (<https://www.gandi.net/fr-FR>)

Activities related to the implementation

Management, use and future update:

- Create the documentation required to future reupload of the dataset.
- Configure the back-office administration.
- Separate time for fix bugs and/or implement little improvements and management.
Define the # of days working on the dashboard.
- For big improvements, it will be necessary to define new specific objectives for the project.

Meetings and discussions

- Introductory meetings, explaining the project and Q&A.
- Weekly meetings to discuss the state of the project (what has been done, what is next and what will be supported by 2DII).
- Start the QA test.

Deliverables

- Documentation for the future updates.
- Back-office and access to it.
- Website in production and bugs-free.
- Open-source data information.



Annex 3 Insurance claims for clay shrink swell

This annex summarises the requirements which must be satisfied in relation to insurance cover for clay shrink swell and the different steps in the process for an insurance claim when homeowners have suffered property damage resulting from a clay shrink swell event.

A3.1 Eligibility requirements for insurance claims

There are three conditions which must be satisfied in relation to any insurance payout:

- First, the homeowner must have a multirisk home insurance policy that explicitly covers natural catastrophes (which is a standard feature in most policies).
- Second, the State must officially recognise the occurrence of a natural catastrophe through an official decree.
- Third, the homeowner must have adhered to all preventative measures mandated by the State before the occurrence of the CSS event.

This third condition emphasizes that homeowners must take a proactive role in safeguarding their property and mitigating potential damage from natural disasters. By doing so, homeowners not only ensure their eligibility for assistance under the Cat Nat scheme (provided other conditions are met) but also contribute significantly to enhancing resilience against natural catastrophes.

Homeowner has multirisk home insurance that covers natural catastrophes

Home insurance contracts covering damage to the house automatically covers natural catastrophes due to application of article L 125-1 du code des assurances: 'Insurance contracts taken out by any natural or legal person other than the State and covering fire damage or any other damage to property located in France, as well as damage to the bodies of land motor vehicles, entitle the insured party to cover against the effects of natural disasters, including those of subsidence due to underground cavities and marl pits on property covered by such contracts.' Even if the home insurance contract seeks to do otherwise, the contract covers catastrophe naturelle ('The contracts referred to in article L. 125-1 are deemed to contain such a clause, notwithstanding any provision to the contrary.' L 125-3 code des assurances).

For homeowners who are living in their house (i.e. not renting) it is not mandatory to have home insurance. For renters and landlords, it is mandatory to have civil liability insurance (Bercy Infos, 2023). Civil liability insurance itself does not cover natural catastrophes because the civil liability insurance covers damage done to a third party by the insured party (i.e. civil liability compensates third parties who suffer damage (such as water damage, fire etc.) for which you are responsible (Bercy Infos, 2023)).

Most insurance proposes a multirisk habitation insurance, including civil liability. According to France's assurance, in 2022 most of the population had a multirisk habitation insurance (France Assureur, 2023).

Official recognition of the occurrence of a natural catastrophe by the State

The State has published a decree on the Official Journal recognising the natural catastrophe. Upon publication of this decree, the Cat Nat clause is activated. It is at this point that insurance companies are obligated to indemnify the affected individuals or properties in accordance with the terms outlined in their multirisk home insurance policies.

Therefore, the activation of the Cat Nat clause is a critical trigger for insurance coverage. The State has a period of two months to issue this decree officially recognizing the state of natural disaster in a city following a request made by the Mayor (L125-1 code des assurances).

However, certain procedural obligations must be met for this declaration to occur. First, the Mayor initiates the request by submitting a file to the Prefect, detailing specific information such as the date, time, and identification of the natural phenomenon, the type of property affected, any previous government declarations of disaster, and any preventive measures taken. As referred to previously, the Mayor has 24 months from the date of occurrence to submit this file to the Prefect.

Subsequently, the Prefect compiles a comprehensive file containing detailed reports from various departments, including the Mayor's files, the list and location of applicant communes, and a technical report on the nature and intensity of the phenomenon. Additionally, the Interministerial Commission convenes to prepare the ministers' decisions regarding the declaration of natural disaster. This Interministerial Commission comprises representatives from the Ministry of the Interior, Ministry for Overseas Departments and Territories, Ministry of Economic Affairs and Finance, and Ministry of Ecology, Sustainable Development and Energy. The CCR serves as the secretariat for these proceedings.

Homeowner has adhered to all preventative measures mandated by the State

The homeowner must be able to demonstrate that he/she has undertaken all preventive measures mandated by the State prior to any reimbursement by the insurance company. These preventive measures are gathered in a single document called the natural risk prevention plan (PPRN).

The PPRN is the main and only reference that homeowners must comply with. Generally, it is readily accessible on the internet and is usually integrated into the local urban development plan which is accessible on the website of each city.

However, for the City of Lyon, it appears particularly difficult to find and access this information which is on the city website. Then even if the information exists, it makes it particularly difficult to the homeowners to comply with it, if it is not accessible. As in every PPRN, it contains a mapping of the CSS risk, an explanation of CSS phenomenon, and preventive measures that need to be done to avoid CSS and to be insured in the event of a natural catastrophe.

When selling a house, the seller is obliged to specify in an annex to the sale contract whether the property is covered by the PPRN and if there have been any declarations of natural disasters in

the area (Article 125-5 code de l'environnement). In addition, since the enactment of the Elan Law (Loi n° 2018-1021 du 23 novembre 2018 portant évolution du logement, de l'aménagement et du numérique), the sale of a buildable plot of land requires a soil study to be provided. This study must include the risk of CSS and must be communicated to the buyer. This ensures that potential buyers are informed about the soil condition, associated risks and any historical natural disaster declarations before finalizing their purchase.

Failure to adhere to these preventative measures, such as building in contravention of the PPRN or neglecting required preventive work within five years of the plan's implementation, absolves the insurer of the obligation to cover damages resulting from a natural catastrophe. Therefore, compliance with these preventive measures not only enhances the property's resilience but also ensures eligibility for insurance coverage in the event of a natural disaster (Georisque, Undated).

A3.2 Details of the cover

Damage covered

The costs covered by the natural disaster clause in the multirisk insurance includes a range of damages and expenses incurred because of the catastrophic event.

- the direct material damage that arises from natural disasters, which would typically be considered uninsurable (damage caused by the abnormal intensity of a natural agent when the usual measures to be taken to prevent such damage could not prevent its occurrence or could not be taken);
- the expenses associated with emergency rehousing for individuals whose primary residences have become uninhabitable due to safety, health, or hygiene concerns stemming from the direct material damage caused by the natural catastrophe (L 125-1 code des assurances);
- the costs of geotechnical studies necessary for the restoration of affected buildings, along with architect and project management fees essential for such restoration efforts, especially when mandated by regulations (L 125-4 code des assurances).

This comprehensive coverage ensures that individuals affected by natural disasters receive necessary assistance not only for repairing property damage but also for addressing immediate housing needs and undertaking essential restoration efforts to rebuild communities affected by the calamity.

Focus on compensation for clay shrink swell

The insurance payouts for losses resulting from property damage caused by a CSS event is capped at the value of the insured property at the time of the loss. This compensation covers the necessary remedial work for existing damage caused by the event. Specifically, it addresses situations where the stability of the building has been compromised or where the property is rendered unsuitable for its intended use because of the ground movement. The compensation is designed to facilitate repairs or improvements that are essential for restoring the property to a



safe and functional condition following damage caused by these environmental factors (L 125-2 code des assurances).

Deductible

<i>Property not intended for professional use</i>	<i>Direct loss and/or damage</i>	<i>€380</i>	<i>Subsidence €1,520</i>
<i>Property intended for professional use</i>	<i>Direct loss and/or damage</i>	<i>10 % minimum €1,140</i>	<i>€3,050</i>
	<i>Business interruption</i>	<i>3 working days minimum €1,140</i>	

Figure 10: Deductible in the case of a Cat Nat event (CRR, Undated)

The *deductible* refers to the amount that an insured party must pay out of pocket before the insurance coverage kicks in. As shown in Figure 10 above, this deductible varies according to different types of damage. For property that is not intended for professional use, the deductible for direct loss and/or damage is usually €300 but in relation to subsidence (e.g. CSS events) the deductible is €1,520. For properties intended for professional use, the deductible for direct loss and/or damage is 10% of the claim amount (with a minimum of €1,140) (and if the property suffers business interruption, the deductible is equivalent to three working days of business interruption costs with a minimum of €1,140) while the deductible for is €3,050.

A3.3 Process which homeowners should follow

This commentary below describes the process homeowners should follow with their insurance company if they suffer property damage caused by a CSS event.

Reporting the damage

When a homeowner suffers property damage from a natural disaster, the first step is for the homeowner to report the damage to the insurance company. This can be done at any time from when the damage occurs up to 30 days after the publication of the natural disaster recognition in the Official Journal.

The homeowner should send a damage report to the insurance company by registered mail, preferably with acknowledgment of receipt. The letter should include the following information (Service Public, 2023):

- full name and address of homeowner
- insurance policy number
- description of the damage (nature, date, time and place)
- an itemized list of all lost or damaged items, along with documents proving the existence and value of the items (such as invoices or photographs)



- an estimate of the financial loss, if the homeowner has coverage for loss of income
- damage caused to third parties (for example, if a tree from your property fell and caused damage to a neighbour's property)
- contact information of any victims (if applicable)

Any insurance payout will only take place after the natural disaster has been declared in the Official Journal as a Cat Nat (Service Public, 2023). If the state of natural disaster is not recognized, the homeowner will not be compensated for the damage suffered and the repair costs, even if the homeowner reported it to the insurance.

Asking for emergency housing

The Law No. 2021-1837 of 28 December 2021, regarding the indemnification of natural disasters, established the right to emergency relocation. This emergency relocation is compensated under the natural disaster guarantee included in home insurance policies (i.e. mandatory contract clause in home insurance contracts). A decree and an order dated 30 December 2022 specified the implementation modalities of this right (Merlen, 2023).

Homeowners can benefit from emergency relocation if their primary residence is insured and suffers the consequences of a natural disaster in different cases:

- The dwelling is rendered uninhabitable for safety, health or hygiene reasons.
- Repair work for damages caused by a natural disaster makes the property uninhabitable.
- The residence is inaccessible, preventing the insurer from assessing the damage, especially when evacuated individuals cannot initially return to their home.

The compensation will only be paid after the homeowner provides proof of the existence and amount of expenses incurred. Those relocated due to a natural disaster must advance the relocation costs and are reimbursed after submitting the necessary documents (hotel receipts, invoices or rent receipts) to their insurer (Merlen, 2023). The emergency relocation will be indemnified even if the state of natural catastrophe is not declared.



Information Box: What can homeowners do in relation to State recognition of a natural catastrophe?

When a natural catastrophe occurs which has not yet been officially recognized by the State, homeowners find themselves in a critical situation. Unfortunately, there appears to be only means to exert indirect pressure on the administrative process to recognise a natural catastrophe has occurred.

By promptly reporting property damage and requesting assistance from local authorities such as the Mayor, homeowners not only address their immediate needs in relation to their property but also lay the groundwork for recognition that a natural catastrophe has occurred.

Simultaneously, homeowners can organise collective efforts such as neighbourhood associations or disaster response groups, which leverage strength in numbers and enable homeowners to amplify their voices and increase collective pressure on authorities to acknowledge the catastrophe. Homeowners can also play a crucial role in raising awareness of the disaster's impact through sharing their experiences via local media, community organizations, and online platforms to engage the broader public. This widespread dissemination of information garners public support and similarly increases the pressure on authorities to take decisive action.

Throughout this process, staying informed about updates from local and state authorities is essential. Continuous engagement and advocacy should seek to ensure that the situation remains in the spotlight until there is official recognition that a natural catastrophe has occurred.

While these must clearly be considered as indirect means for homeowners to improve their situation following property damage caused by a CSS event, by forging strong connections and mobilizing the community to increase public awareness, homeowners can have some influence to pave the way for effective disaster response and recovery.

A3.4 Insurance claims against builders

In France, all home builders are legally required to subscribe to a ten-year guarantee, known as the *garantie décennale*. This guarantee protects the builder against any construction defects that may arise within ten years from the delivery of the house, particularly if the house was built without adhering to regulations concerning the management of CSS. In the event of a natural catastrophe which is not recognised by the State, the homeowner can invoke the ten-year guarantee if the damage could have been avoided had the house been constructed properly. To do so, the homeowner must send a registered letter to the builder's insurance company, detailing the damages and requesting an expert assessment for compensation. If the claim is denied, the homeowner has the option to seek recognition of their claim through legal action (Code civil, article L1792-4-1, Service Public, 2024).

