CLIMAAX
climate ready regions

Deliverable Phase 1 – Climate risk assessment

RISC-RA

France, La Réunion

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HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk

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1 Document Information

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5 Abbreviations and acronyms

Abbreviation / acronym	Description
ADEME	French Agency for Ecological Transition
AGORAH	Réunion Island's urban planning agency
BRGM	French Geological Survey
BRIO	Building Resilience in the Indian Ocean
BRIO	Building Resilience in the Indian Ocean
CATNAT	Compensation scheme for natural disasters
CCAS	Municipal Center of Social Action
CEREMA	Centre for Studies on Risks, the Environment, Mobility and Urban Planning
CMIP6	Coupled Model Intercomparison Project Phase 6
CNL	National Housing Confederation
CNRS	National Center of Scientific Research
CRA	Climate risk assessment
DAAF	Department of Food, Agriculture and Forestry
DEAL	Department of Environment, Planning, and Housing
DIROI	Indian Ocean Regional Directorate
DROM	Département et Région d’Outre-mer / Overseas Department and Region
EARDF	European Agricultural Fund for Rural Development
ERDF	European Regional Development Fund
ESF+	European Social Fund Plus
FSOM	Fonds de Secours des Outre-mer / Overseas Aid Fund
GCLA	General code of local authorities
INSEE	The National Institute of Statistics and Economic Studies
IO	Indian Ocean
IRIS	Îlots regroupés pour l'information statistique (Statistical information groupings)
OPAR	Observatoire de Physique de l'Atmosphère de La Réunion / Atmospheric Physics Observatory of La Réunion

OSU-Réunion	Universe Sciences Observatory of La Réunion
PCAET	Plan Climat Air Energie Territorial / Territorial Climate-Air-Energy Plan
PCS	Plan Communal de Sauvegarde / Local Emergency Plan
PDU	Plan de Déplacement Urbain / Urban Travel Plan
PIROI	French Red Cross's International Operations Division
PLH	Plan Local de l'Habitat / Local Housing Plan
PLU	Plan Local d'Urbanisme / Local Urban Development Plan
PPE	Programmation Pluriannuelle de l'Energie / Multi-Year Energy Plan
PPRI	Plan de Prévention des Risques Inondation / Flood Risk Prevention Plan
PPRL	Plan de Prévention des Risques Littoraux / Coastal Risk Prevention Plan
PRIT	Planification Régionale d'Intermodalité / Regional Intermodal Transport Plan
RISC-RA	Réunion Island's Climate Risks Atlas
RPCC	Regional Panel on Climate Change
RSMC	Regional Specialized Meteorological Centre
SAR	Schéma d'Aménagement Régional
SAR	Schéma d'Aménagement Régional / Regional Land Development Plan
SCoT	Schéma de Cohérence Territoriale / Territorial Coherence Scheme
SDAGE	Schéma Directeur d'Aménagement et de Gestion des Eaux / Water Management Master Plan
SI	Supplementary Information
SRB	Schéma Régional de la Biomasse / Regional Biomass Scheme
SRCAE	Schéma Régional Climat Air Energie / Regional Climate, Air, and Energy Scheme
SRIT	Schéma Régional des Infrastructures et des Transports / Regional Transport Infrastructure Scheme
SSP	Shared-Socioeconomic Pathways
SWIO	South Western Indian Ocean
WMO	World Meteorological Organization

6 Executive summary

Réunion Island's Climate Risks Atlas project (RISC-RA) aims to carry out an assessment of climate risks on Réunion Island, a French overseas territory exposed to intense natural hazards. Réunion Island's Regional council, hereafter called Region Réunion, a local public authority in charge of sustainable development and regional planning, has been managing the project since 1st October 2024 in collaboration with a scientific research group.

6.1 Phase 1 deliverable: an initial assessment of climate risks using the CLIMAAX toolbox

This deliverable presents the organization, methodology and results of the RISC-RA project at the end of the first 6 months of work. The initial climate risks assessment has prioritized two main climate hazards: **Droughts** and **Heavy Rainfall** events, each already posing substantial and growing threats to socio-economic stability, infrastructure integrity, public health, and environmental sustainability. The general CLIMAAX methodology was adapted to the local context, using high-resolution climate data and local exposure and vulnerability datasets. The first phase of RISC-RA was also devoted to setting up the team's operational organization, establishing project governance and making initial contacts with external stakeholders.

Regarding the two main risks addressed during this phase, the following observations and results can be drawn:

<u>Drought Risk</u>: Droughts on Réunion Island are slow-onset hazards caused by prolonged periods of below-normal rainfall. The territory experienced extreme drought in December 2024 and January 2025, the driest months recorded for over 50 years. The analysis using regional climate projections indicates an increase in both intensity and spatial extent of drought risk, particularly in the northern and northwestern regions.

<u>Extreme Rainfall Risk</u>: the island holds most world records for rainfall duration over time intervals ranging from 12 hours (1144 mm) to 15 days (6083 mm). Heavy rainfall is a sudden-onset hazard expected to intensify, with projections indicating extreme rainfall events becoming more frequent, notably affecting northern, eastern, and southern coastal regions. Historical analysis identified a threshold of approximately 220 mm/day, regularly triggering catastrophic events.

6.2 Conclusion and next steps

Phase 1 provided significant insights into regional climate vulnerabilities and risks, particularly highlighting drought and extreme rainfall as pressing concerns. This year 2025 was a perfect example of this, with a persistent heatwave during the first's months, a severe drought in the northeastern areas, including water unavailability and water restrictions usages. This was followed by Cyclone Garance, one of the strongest cyclones experienced in La Reunion with devastating impacts.

The climate risks analysis produced during phase 1 will serve as the first version of the Risk Atlas, which will be refined and discussed with local public authorities and practitioners. The findings of deliverable no. 1 will be used as the basis for the first local workshop to present the RISC-RA project to local stakeholders, such as the Drought Committee, for example.

The preliminary results for both historical data and projection will be improved in Phase 2 with case studies for the validation of vulnerability indicators and the extended analysis of heavy rainfall. At the same time, one or two new Workflow(s) will be explored.

7 Introduction

7.1 Background

Réunion Island is a 55 km-diameter tropical volcanic island in the South-Western Indian Ocean (SWIO) with significant topography (up to 3000m) influencing its natural hazards. Its population of 885,700 is concentrated coastally. The island features great ethnic diversity (European, Malagasy, Indian, Asian, African origins). Socio-economically, it faces challenges: a 19% unemployment rate in 2023 (over double mainland France's 7%) contributes to poverty and wealth inequality, heightening vulnerability to climate risks.

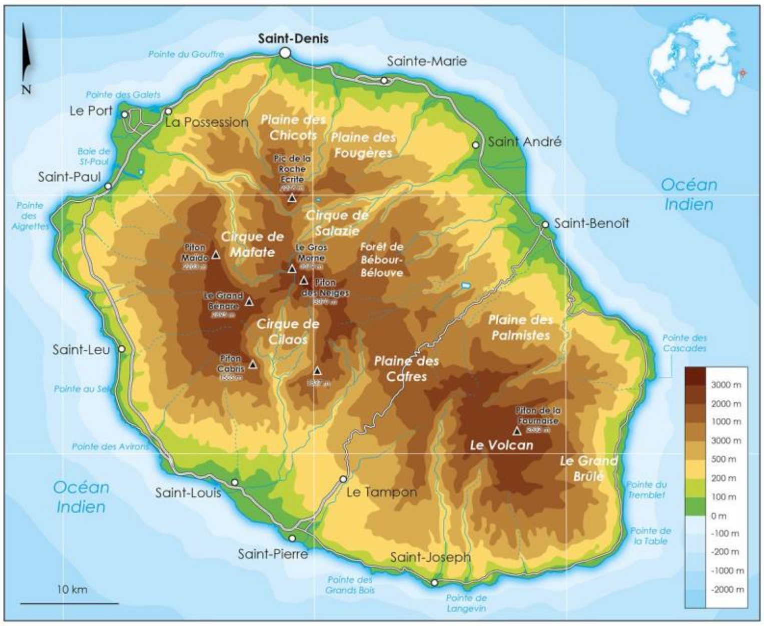


Figure 7-1: Geographical context of La Réunion territory (Bart, 2016)

The Réunion Regional Council, hereafter called Region Réunion, is the local authority since 1982, it manages economic development, research, training, sustainable development, and land use planning. Its key planning document, the SAR (Regional Land Development Plan), sets guidelines for sustainable development and environmental protection, including climate adaptation strategies. The SAR is currently under revision to meet 2050 challenges. In 2023, the president of Region Réunion announced plans to create a Regional Panel on Climate Change (RPCC).

7.2 Main objectives of the project

This project will conduct Réunion Island's first comprehensive regional Climate Risk Assessment (CRA), focusing on significant hazards and vulnerable sectors. Using observed and projected climate, vulnerability, and exposure data under various scenarios, the RISC-RA project will examine future climate change impacts on key sectors (infrastructure, water, health, agriculture, etc.), producing a climate risk atlas.

These outputs, guided by the CLIMAAX methodology adapted for La Réunion, aim to enhance local climate risk knowledge and awareness. The analysis will clarify how territorial vulnerability shapes risk, providing standardized, spatialized risk indicators for public bodies and scientists.

Ultimately, the CRA and atlas will serve as decision-support tools for risk management and adaptation, notably informing the revision of the SAR and related plans. The project will also support the establishment of the RPCC (or GREC), foster collaboration between experts, decision-makers, and the public, and aid Region Réunion's pursuit of health, energy, and food sovereignty goals impacted by climate risks.

7.3 Project team

The RISC-RA project team is composed of a scientific research group working in collaboration with the Réunion Regional Council. The Core Team include:

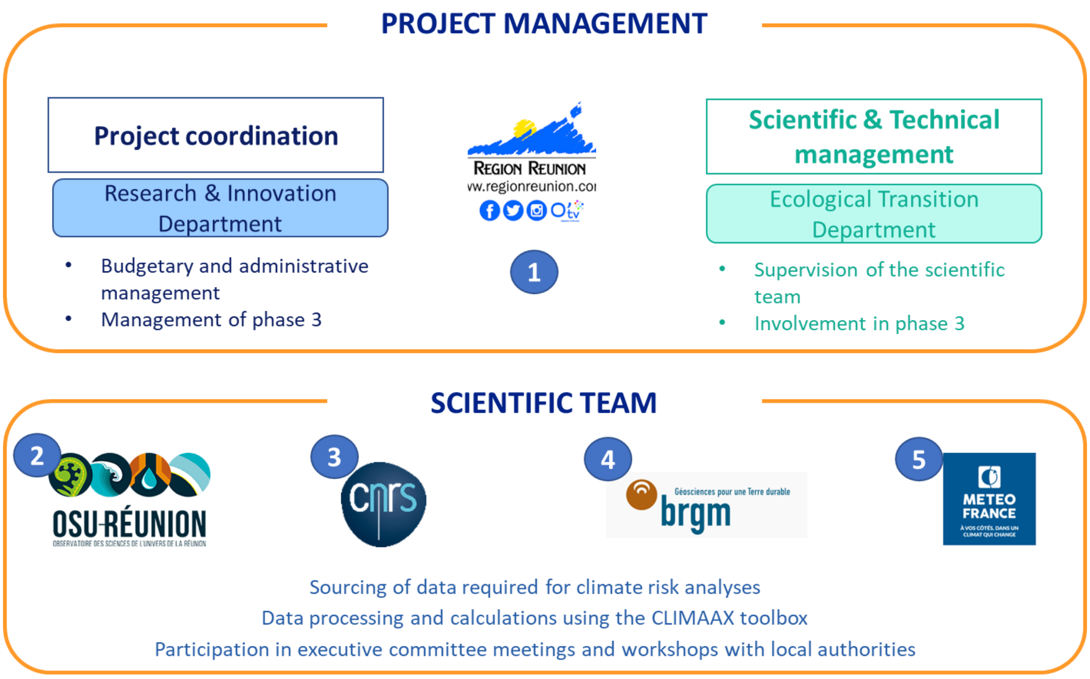


Figure 7-2 : RISC-RA Project organizational chart

1: **Kévin Lamy**, Natural Risks and Climate Project Manager, Ecological Transition Department, and **Elodie Marpinard**, Research and Innovation Officer, Research, Innovation and Technologies Department, Region Réunion
2: **Nils Poncet**, Scientific provider of the RISC-RA project, OSU-Réunion.
3: **Jean-Pierre Cammas**, Research Director, CNRS, OSU-Réunion.
4: **Rémy Belon**, French Geological Survey on the coastal risks (BRGM).
5: **Clotilde Dubois**, Climate Services, Indian Ocean Regional Directorate (DIROI) of Météo-France.

Additional stakeholders will be involved through participatory processes that strengthen collaboration and inclusivity.

7.4 Outline of the document’s structure

The document is structured as follows.

Section 2 presents the operational stages of a CRA in Réunion Island, including scoping, risk exploration, and risk analysis. Preliminary findings for the key risk assessment and the monitoring and evaluation phase will conclude this section. Section 3 briefly summarizes the main conclusions and key findings of this project phase. Section 4 describes the connection between this deliverable, its outputs, and the planned activities for the following project phases. Finally, Section 5 and section 6 list the supportive documentation and references produced during this phase.

8 Climate risk assessment – phase 1

8.1 Scoping

8.1.1 Objectives, purpose and outcomes

This CRA assesses current and future climate risks on Réunion Island by integrating hazard, vulnerability, and exposure data. Key outputs include **risk maps**, **indicators**, a **regional climate risk atlas**, and **targeted workshops**. The overarching goal is to enhance climate risk knowledge among local authorities at all governance levels, guiding the development and implementation of adaptation strategies within risk management and planning documents.

The findings and the knowledge derived from this climate risk assessment will achieve a larger purpose than simply risk mapping. Indeed, the CRA and the associated atlas are intended to increase climate risk knowledge for local public authorities in La Réunion at all levels of governance (regional, municipal and inter-municipal). Specifically, the CRA aims to:

- Inform the revision of the Regional Land Development Plan (SAR). The SAR is a prescriptive planning document in the French overseas territories, providing guidelines for local authorities in implementing their local development and planning strategies (PLU, SCoT)., ensuring consistency with other local plans (PLU, SCoT).
- Provide data for the revision of natural risk prevention plans (PPRI, PPRL), which regulate land use based on risk.
- Contribute to the establishment of the RPCC.
- Improve climate change and climate risks understanding among non-experts (municipalities, public).

8.1.2 Limitations, boundaries and constraints

La Réunion's remoteness and unique characteristics pose challenges. Key constraints include:

The spatial and temporal data resolution and the **lack of common datasets**. The region is outside of the range of most European datasets requiring additional data gathering and processing to be compatible with the CLIMAAX toolbox. In addition, its small size makes the island invisible in most global models (resolution ~150 km). However, regional and local datasets are available or under development. In addition, there is a lack of reliable sub-daily climate data to assess highly dynamical hazards such as heavy rainfall and flash floods.

Inadequate workflows for a mountainous tropical island. Standard continental risk assessment workflows may be ill-suited for Réunion's complex tropical environment, particularly for flash floods driven by runoff and artificialization.

8.1.3 Context

8.1.3.1 Current Local Risk Assessment

Réunion island has extensive atmospheric physics and weather observation infrastructure such as the OPAR (Observatoire de Physique de l'Atmosphère de La Réunion, GAW/WMO Global Station, ACTRIS National Facility, and ICOS Station Class 2), 96 weather stations, 2 weather radars, and other important means for weather observation and predictions. Moreover, the Direction of Météo-France in La Réunion has been formally designated as the Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones for the SWIO by the World Meteorological Organization (WMO) in 1993. Thus, cyclones and other weather-related hazards are well documented. However, despite this high spatial density of weather stations, records do not always correspond to the impact observed particularly in the case of cyclonic winds. While climate and hazard observation systems are already in place but require further enhancement; the most critical gap, however, is the establishment of a **comprehensive impact observation system** and corresponding long-term metrics. In terms of climatology, data depth is lacking for reliable climate statistics and trends, particularly for extreme weather events.

A recent project, BRIO (Building Resilience in the Indian Ocean), produced a gridded climate dataset from observation. It also produced historical and future climate data at a resolution of 3 km using statistical downscaling techniques applied to CMIP6 models. Up to date, no study has yet been carried out to comprehensively assess natural risks (hazard, exposure and vulnerability) such as drought and their evolution with these brand-new datasets. No comprehensive climatic risk analysis is available for La Réunion. Only a few studies exist to assess specifics impacts of climate hazard on Réunion Island:

- The impact of drought and temperature on invasive seedling and ecological diversity (Christina et al., 2023).
- The impact of drought and extreme rainfall events on sugarcane yield (Christina et al., 2021, 2023).
- The effect of climate change on the expansion of some species of mosquitoes, leading to the risk of disease transmission on the territory (Lamy et al., 2023).
- The health risk due to UV solar exposure (Cadet et al., 2020; Lamy et al., 2018).

Despite knowledge gaps, existing risk management includes efficient alert systems (incl. FR-ALERT), post-cyclone safeguard phases, insurance/compensation funds (CATNAT, FSOM), and Red Cross (PIROI) emergency response.

8.1.3.2 Placing the Problem in a Wider Development Context

The main issue for La Réunion resilience is the absence of comprehensive risk impact studies linking all the hazards, vulnerability and exposure existing local datasets. There is a particular lack of a fundamental document that structures and strengthens risk knowledge on the territory and which could serve as a guide to help link national risk management strategies to local challenges. The project seeks to consider bottom-up needs in terms of risk reduction and management by addressing them into the top-down regulation and policies.

Other issues could be raised in La Réunion context's:

•**The lack of qualified personnel** (whether researchers or engineers) and **the lack of expertise on the subject** for managers or local decision-makers. There is a need to strengthen the human resources over the island in the field of adaptation to climate risks.

•**The necessity to improve the consideration** of the island's specific characteristics in French building and insurance laws.

Further limitations that are not specific to the territory may include:

•**Knowledge gap of climate risks** such as the urban areas resilience in the context of rapid population growth, housing demand and soil artificialization.

•**The lack of transdisciplinary studies** ranging from social and economical sciences to natural sciences and constructed with stakeholders.

•**An inefficient Science-Society interface**. While a fair amount of fundamental and applied research is produced in La Réunion. The output generated from these studies is often not directly usable for strategy and planning at a public policy level. This results in a disconnection between Science and Society, where research findings are transferred and considered enough in public policy documents.

8.1.3.3 Institutional Context

La Réunion, as a French overseas region, adheres to French and EU regulations for environmental and risk management (e.g., Floods Directive 2007/60/EC). Climate adaptation is guided by policies and plans at multiple levels:

- **Regional Land Development Plan (SAR):** The SAR, currently under revision, is the primary land-use planning document for La Réunion at a regional scale. It sets fundamental guidelines for land use, sustainable development, and environmental protection. The CRA will contribute to the reflection on the revised SAR, particularly regarding climate change adaptation.
- **SAR individualized "Climate, Air, and Energy" Chapter :** Formerly known as the "**Regional Climate, Air, and Energy Scheme"** (SRCAE). This chapter provides a diagnostic and a strategy regarding atmospheric pollutant sources and air quality, heating network or objectives for preserving the carbon absorption capacity of soils and natural environments. It sets targets for the region and for the 2030 and 2050 timeframes, in terms of reducing energy consumption, preserving and increasing carbon absorption by soils and natural environments, and reducing greenhouse gas emissions (Article R4433-2 – "Code général des collectivités territoriales"). Finally, it includes a study of the **territory's vulnerability to climate change** and **a regional adaptation strategy**.
- **Multi-Year Energy Plan (PPE):** The 2019-2028 PPE guides energy policy, including renewable energy development and adaptation to climate change.
- Other Relevant Documents which may benefit from the CRA such as transport, mobility, biodiversity preservation or biomass planning documents.

The CRA will also be considered relevant for informing plans at the sub-regional level:

- Inter-communal urban or territorial planning schemes such as the territorial coherence plan (SCOT) or the territorial climate-air-energy plan (PCAET) which is produced by all five intermunicipal bodies of La Réunion.
- Municipal plans such as the local urban planning (PLU), plans relative to the prevention of natural risks (flooding : **PPRI**, coastal : **PPRL**) and finally local emergency plan **(PCS)**, acts as a link between local risk prevention and crisis management policies.

8.1.3.4 Mapping Climate Impacts Across Key Sectors

As a remote territory, with limited size or predisposition to natural disasters, Réunion Island is particularly threatened by climate change. Due to geographical constraints, its population and economic activities are concentrated in the coastal zone. Its economy relies on a few sectors that are particularly vulnerable to natural hazards and most likely to be impacted by climate change:

➢ **The agricultural sector**: Producing sugarcane, vanilla, fruits, and vegetables, agriculture is a key sector for the territory. Between 2010 and 2022, the Agricultural Office reported compensation of at least €43M for the agricultural sector due to tropical cyclone (TC) impacts alone. Furthermore, France Insurance Federation estimated damages of around €100M and €169M for Cyclones Belal (2024) and Dina (2002), respectively. According to Météo-France, it is likely that the frequency of major tropical cyclones and rapid intensification events have increased over the past 40 years due to increased sea surface temperatures. Beyond cyclones, droughts are a growing threat to agriculture on Réunion Island (Christina et al., 2024) and heavy rains events could also highly impact the agricultural sector (Christina et al., 2021).

➢ **Energy supply:** Réunion Island's energy sector is in transition to achieve energy self-sufficiency by 2030 through renewable energy alternatives (Selosse et al., 2018). Nonetheless, energy security is major concern. After TC Garance struck in 2025, 180,000 customers (41% of the island's customers) were left without power, some for almost a month.

- **Biodiversity and Ecosystems:** As a biodiversity hotpot**,** Réunion Island is home to a wide variety of terrestrial and marine species. These specific ecosystems are threatened by climate change direct and indirect impacts (ocean acidification, habitat loss, invasive species).
- **Infrastructure and Transport**: Cyclones, coastal floods, flash floods and landslides can severely impact the island infrastructure including transport and telecommunication networks. The main airport is located by the sea making it vulnerable to wind gusts and coastal floods, which can interrupt air connections reducing aid and food supply in case of disaster. In long-term it is threatened by coastal erosion. La Réunion's roads are frequently closed due to severe weather or landslides, disrupting mobility and connections between towns.
- **Housing:** Following TC Garance in 2025, major impacts were reported on social housing units. These buildings are home to the poorest and most vulnerable population of the Island.
- **Water supply:** Due to its complex orography, its tropical climate and frequent TC passages, Réunion Island experiences highly variable precipitation patterns, both spatially and temporally. The annual mean precipitation ranges from 500mm per year on the west coast to more than 12 000 mm next to the volcano in the east. This distribution of water resources is problematic during drought periods, impacting regularly and more frequently the island. An underground aqueduct was built to transfer water from the eastern to the western part of the island for irrigation and human use. In addition, the water supply can be severely affected by a TC strike due to broken pipes and water pollution caused by run-off.
- **Tourism:** Tourism is a growing sector in La Réunion. It accounted for 3.3% of the total value added in 2019 and employed 13,550 people in 2018 (Perrain et al., 2022). For all the reasons mentioned above, tourism activities are threatened by natural hazards linked to climate change (trail closures, water pollution, network cuts, ecosystem degradation…).

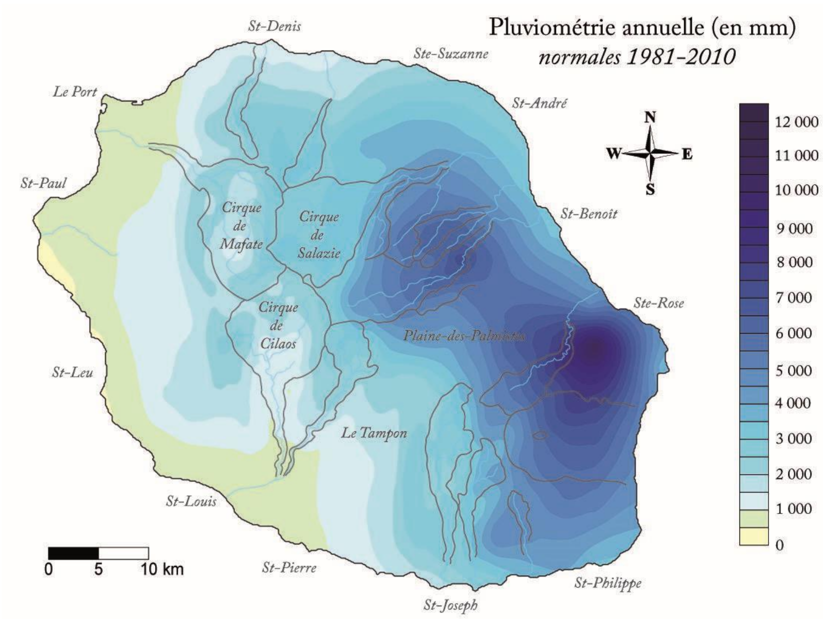


Figure 8-1: Mean annual rainfall (mm) over 1981-2010 - Météo-France

8.1.4 Outside influences

La Réunion depends on imports, rendering it sensitive to global supply disruptions (e.g., price volatility, rising transport costs). Although food sovereignty has been a key development target for La Réunion, the territory remains far from achieving it, owing to persistently high import rates.

Another external factor is the growing concern about illegal immigration. While this issue is relatively low and infrequent on La Réunion, it poses a major problem on Mayotte—another French island in the Indian Ocean (IO) situated closer to mainland Africa. With the acceleration of climate change and the increase in geopolitical tensions and conflicts, this challenge may increasingly affect La Réunion in the future (Cole & Cabestan, 2024; Wu-Tiu-Yen, 2015).

8.1.4.1 Possible Adaptation Interventions

Several projects aim to increase La Réunion's climate resilience:

- La Réunion's coastal observatory which produce knowledge on coastal risks, improve the knowledge transfer and contribute to a better integrated coastal management.
- The "Knowledge and Solution for Climate Change Adaptation of Overseas Territories" project, piloted by the CNRS, is carrying a review of the scientific literature on observed and expected climate change in French overseas territories, its impacts by sector, and a synthesis of solutions for adapting to climate change in these regions.
- The on-going research project "Barriers, levers and constraints to Adaptation in Territorial Public Policy". This project is placed at the interface of social sciences, political sciences and climate sciences, it is led locally by the CNRS.
- The on-going creation of a RPCC whose goal is to address the gap listed in section 2.1.2. The RPECC will conduct territorial research and expertise on climate impact and adaptation, it will organize and improve the science-society interface; and it work to improve the coordination, cooperation, and finance of climate change adaptation in La Réunion, but also among the territory of the South-West Indian Region

8.1.5 Participation and risk ownership

Up to date, the main stakeholders met during various meetings, including executive committees, gathering:

- Two departments of Region Réunion: the Ecological Transition Direction, the Research and Innovation Direction, the GIS Department and the Planning and Housing Direction.
- A scientific group composed of members from four institutions: OSU-R, CNRS, University of La Réunion, Météo-France and BRGM

This consortium enables interdisciplinary scientific collaboration to cross-reference data and assess risks in the region. This consortium is intended to be the beginning of a long-term collaboration leading to the creation of the RPCC.

The first phase of establishing contacts for data collection has been undertaken by the consortium with some of the practitioners that will be part of the project workshop of Phase 2:

- DEAL (Department of Environment, Planning, and Housing): The DEAL represents the French government (Ministry of Ecological Transition and Territorial Cohesion and Ministry of Energy Transition). The DEAL plays a key role in sustainability including environmental and risk management through the creation of the PPR, sustainable development or resources preservation.
- INSEE: The National Institute of Statistics and Economic Studies collects, analyses and disseminates information on the French economy and society
- AGORAH: Réunion Island's urban planning agency. For three decades, it has capitalized on a wide range of observational data, providing cross-referenced analyses to inform public policy.
- Office de l'eau: The Water Office is responsible for facilitating various actions of common interest in the field of water and aquatic environment management, to help achieve the objectives of the water development and management master plans (SDAGE).

Future phases will integrate more research bodies, civil society groups, and local media.

8.1.5.1 Vulnerable groups

About 36% of the population lives in poverty, with particularly high risk for communities in coastal zones, elderly or ill individuals, those in substandard housing, and isolated areas (e.g., cirque de Mafate). Entities like CCAS (municipal social action centers) and various NGOs (consumer rights associations, organizations assisting residents in substandard housing, associations dedicated to child protection, housing advocacy groups) represent these groups, but their current involvement is limited. Strengthening their participation is critical to address wide-ranging socio-economic vulnerabilities.

8.1.5.2 Risk Ownership

French law makes **the State the primary risk and security manager**. However, other competencies crucial for climate risk, are the responsibility of territorial institutions at different levels.

- At the regional level, Region Réunion (P.I. of this project) acts as the main authority in charge of regional planning, economic development, and environmental policy
- At the departmental level, the department oversees departmental roads (more than half of La Réunion road network), including flood-prone roads at ravine crossings. It is also responsible for protecting, managing and opening natural sites to the public. Finally, the department is responsible for developing social policies to reduce vulnerability by minimizing social inequalities.
- At the intercommunal level (EPCI): the intercommunal Bodies are responsible for local planning and implementation of climate actions.
- At the local level, municipalities manage local planning and implement adaptation actions.

In addition, multiple government services are present in overseas territories. They act as local relays for decisions taken by the central administration and manage government services at local level. They also are responsible for regional cooperation and external communication. Among theses local representation of the French Government, the services most related to this project are :

- Department of Environment, Planning, and Housing (DEAL) : The DEAL represents the French government (Ministry of Ecological Transition and Territorial Cohesion and Ministry of Energy Transition). The DEAL plays a key role in sustainability including environmental and risk management through the creation of the PPR, sustainable development or resources preservation.
- Réunion's Department of Food, Agriculture and Forestry (DAAF): The DAAF also represents the French government. It promotes agricultural practices that protect public health, food safety, public health, food safety, the environment and animal welfare. It coordinates interministerial initiatives such as the protection and management of agricultural and forestry areas.

For this project, Region Réunion bears an overall responsibility for the CRA, the scientific Partner is responsible for conducting the technical aspects of the risk assessment; the institutional Partners provide data, expertise, and support; and local authorities are responsible for integrating CRA findings into local planning and implementing adaptation actions.

8.1.5.3 Level of risk

The project's primary aim is to safeguard human life and ensure the security of people, property, and essential infrastructure, with special attention paid to particularly vulnerable groups (isolated at-risk housing, homeless individuals, healthcare facilities, etc.). Beyond immediate protection, the goal is also to maintain and swiftly restore the population's quality of life by ensuring access to drinking water, electricity, and transportation infrastructure following the occurrence of a natural hazard (e.g., a tropical cyclone).

From an economic perspective, a temporary halt in activities may be unavoidable during major climate events. However, all mobilized services work to limit this interruption, while protecting public health and well-being and reducing the duration of water and power outages. Beyond the urgent response, the priority lies in preserving public safety and resilience, safeguarding critical infrastructure, maintaining a satisfactory quality of life, and supporting the rapid resumption of economic activities.

8.1.5.4 Communication

The project's results will be communicated to various stakeholders via the planned documents: a scientific version and a simplified version of the atlas of climate risk projections. Secondly, communication will be aimed at municipal and inter municipalities bodies. We will also share the results during several dedicated workshops with government departments and local authorities or NGOs, who have a role to play in informing, monitoring and raising awareness of risk, as well as with scientists. Online communication about the project will be set up to inform the general public through various media, as well as results access via an open data portal.

8.2 Risk Exploration

8.2.1 Screen risks (selection of main hazards)

Réunion island is a highly impacted by natural hazards, particularly extreme weather events. The Central Reinsurance Fund (CCR) estimates the average annual cost of historical damage, all hazards combined, at €9 million for La Réunion. It is projected to reach 30M€ per year for cyclones alone. Tropical cyclones are the most significant threat, generating multiple hazards (destructive winds, heavy rainfall, river, coastal and flash floods and landslides). In total, Réunion Island is exposed to 7 out of 8 of the major natural risks.

8.2.1.1 Droughts

Droughts can affect Réunion island with economic losses, a drop in agricultural yields (Christina et al., 2021, 2023) leading to the scarcity of certain food products and limited access to water for the population. The west coast is the driest part of the island, and the one most affected by the pressure of access to water resources. However, certain rain-fed communes on the east coast may also be temporally vulnerable to drought, depending on the scarcity of drinking water supply infrastructures (water catchments). The territory experienced an extreme drought in December 2024 and January 2025, the driest recorded months in 50 years of measurements. This drought supports and reinforces the credibility of simulations from the BRIO project (described below) showing a drying out and lengthening of the dry season consecutive to an offset of the wet season (Leroux et al., 2024).

8.2.1.2 Tropical cyclones and wind-related damage:

Cyclonic winds pose a major threat across the island. While all locations may be impacted by damaging winds on the island, coastal cities are more exposed and vulnerable due to higher population density and human activities. Communication and energy supply networks are regularly affected by cyclonic winds, further isolating rural population. Future TC activity is likely to decrease slightly in terms of frequency, but increase in terms of intensity, with a greater proportion of intense tropical cyclones (Cattiaux et al., 2020; Leroux et al., 2024). These trends would suggest an increase of the wind related risk as well as heavy rainfall on the territory.

8.2.1.3 Heavy Rainfall:

The island holds most world records for rainfall amount for time intervals ranging from 12 hours (1144 mm) to 15 days (6083 mm). Recently, tropical TC Garance in February 2025 brought up to 140 mm in one hour and more than 250 mm in three hours on the north coast leading to catastrophic floods in Saint-Denis urban area. Mainly but not exclusively induced by TC, these extreme precipitation events generate two types of risks on the territory:

- ➢ Run-off generated floods and torrential floods
- ➢ Land movements (rock or boulder falls, landslides, mudflows and gullying). They are frequent on the island, particularly in the mountainous region and in the recesses carved out by the main rivers. Large-scale landslides can include the collapse of ramparts and landslides affecting islets in the 3 cirques, mobilizing volumes more than one million m^3 and sometimes dozens of fatalities. 6% of the island's inhabitants (51 295 people) are exposed to moderate and high risks of landslides affecting human lives, goods, housing, public infrastructures as well population health due to debris and pollution input.

Although there is no significant trend in the frequency of extreme precipitation events, the intensity of these events is likely to increase in the future due to the intensification of tropical cyclones and the increase in atmospheric water content (Clausius Clapeyron relation).

8.2.1.4 Floods (including flash floods)

Consecutives to heavy rainfall over a complex topography, the island is prone to torrential flooding that are most of the time flash floods. In addition, heavy runoff can saturate rainwater collection systems causing dangerous flooding outside the riverbed, mainly in man-made waterproofed areas (run-off generated floods). Around 200,000 of Réunion's inhabitants live in potentially flood-prone areas and 13.2% of the population (114,269 people) is exposed directly to flood risks. The low altitude coastal cities, often crossed by ravines, are mainly exposed to floods and runoff consequences while inland villages can suffer from long periods of isolation without drinking water or electricity due to network outages.

8.2.1.5 Wildfires

The most fire-prone areas are the highly combustible cane fields to the east and the scrubland and dry savannah to the west of the island. Among vegetation fires, forest fires are most likely to occur in the Roche Écrite, Montagne, Grande Chaloupe, Hauts Sous le Vent, Étang-Salé and Volcan areas. These are the areas with the most combustible plant formations and that experienced the longest, most pronounced drought. There are several hundred fires a year on Réunion Island, and a major fire every 15 to 20 years on average. The austral winter is the most propitious period for forest fires, due to the combination of trade winds and drought. Recently, in October 2010, over 800 ha of forest burned at Le Maïdo, then in 2011, fire consumed a further 2,800 ha of forest. Both fires affected the National Park and UNESCO World Heritage sites.

8.2.1.6 Coastal Floods (tsunami or large swell events)

Two types of swells can lead to huge coastal flooding on Réunion Island: (1) austral swells concerning mainly the southern and western coasts and (2) cyclonic swells that could occur all around the island. By eroding, these events can suddenly modify the coastline and affect littoral housing and infrastructures. 5000 people are exposed to this risk in La Réunion. As in 2004 consecutive to the Sumatra earthquake, tsunamis hit the island.

8.2.1.7 Heatwaves

Heatwaves affect low-elevation coastal areas (< 150m) on the island where more than half of the population resides (Merceron, 2017). In Réunion Island, heatwaves occur during the austral summer in conjunction with the rainy season. Often coupled with high humidity levels, heat waves represent a non-negligible mortality rate in the French overseas territories (Pascal et al., 2022). They mainly affect the elderly population, but can also have consequences for all age groups, particularly with the outbreak of epidemics carried by mosquitoes as the Dengue (Lamy et al., 2023). In the capital (Saint-Denis), a doubling of the number of hot days (> 31°C) and nights in the capital were recorded in the 1970-2021 period. 16 of the 20 heat waves observed between 1995 and 2021 have occurred since 2010. This trend is expected to continue and intensify with a threshold of 31 degrees that could be reached 6 months per year.

8.2.2 Data

In this analysis, due to the territory specificities, only regional or local data were used. Global data are in fact irrelevant for risk assessment on the territory (see section 2.1.1). For hazard data, a recent climate dataset has been set by National climate services that cover the SWIO: BRIO dataset. The BRIO project has produced well-documented, finescale, timely, reliable, and accessible regional to local climate information for the 21st century tailored for the Indian Ocean Commission (IOC) member countries: Madagascar, La Réunion, Mauritius, Comoros and Seychelles archipelagos (Leroux et al., 2024). With a combined statistical and dynamical downscaling approach, BRIO provides historical simulations and future projections following different greenhouse emission scenarios at a resolution of 12km, further corrected and interpolated at 3km. Gridded observations have been interpolated on the same grid over Réunion Island.

Vulnerability and exposure data come from different data practitioners and services:

- BRGM : observed landslides and exposed areas
- INSEE : data relative to demography, economy, income and society.
- CORINE : land cover data
- CIRAD for agricultural land use (THEIA-DATATERRA-GABIR datasets)
- AGORAH : urbanism data

Those are the non-exhaustive list of the main institutes and datasets. For more details about the data for each risk used or planned to be used, their temporal and spatial resolution and other relevant information, the reader is invited to refer to the supplementary information (SI).

8.2.3 Workflow selection

We chose workflows that could be rapidly deployed within the timeframe of phase 1, in terms of data accessibility and usability as well as workflow application feasibility. Another criterion was relevance to recent events in the region for example the severe drought in 2025 and the recent destructive cyclones in the Indian Ocean region bringing heavy rainfall.

8.2.3.1 Drought — Relative Drought

Drought was selected as a workflow because the territory already experiences severe droughts which impacts populations as well as to agriculture, heavily dependent on irrigation for certain types of crops, and it also impacts hydro-electrical production in some parts of the island (see 2.2.1). Also, the first analysis of the BRIO climate projection showed a longer dry season and a late arrival of the wet season at the regional scale of the IO, which is also observed in the recent years.

8.2.3.2 Heavy Rainfall

Heavy rainfall was selected as a workflow because the territory is famous for its record rainfall for multiple durations. These events are associated with cascading events such as floodings, landslides or mudflows resulting in severe impacts on population, including deaths, on property and on strategic infrastructure, including complete destruction of road and bridges (see 2.2.1).

8.2.4 Scenarios

Réunion Island is showing rapidly growing population growth associated with urban development. As La Réunion regularly experiences major natural hazards such as Cyclone, Flooding, Droughts or Landslides, both short-term changes could be beneficial to increase resilience but also medium - term and long-term. We will have a particular focus for the climatological mid-term horizon (2035-2065) because it aligns with the SAR horizon of 2050, therefore reinforcing the ability of CLIMAAX/RISK RA results to be incorporated into public policy documents. The climate scenarios we will use will be SSP1-2.6, SSP2-4.5 and SSP5-.8.5 (Meinshausen et al., 2020). Since we do not use EURO-CODEX and CLIMAAX pre-computed datasets of Hazard assessment, we choose these scenarios because of their availability in the best regional climate dataset that we dispose of from the BRIO project (Leroux et al., 2024).

8.3 Risk Analysis

8.3.1 Workflow #1: Drought — Relative Drought

Hazard data	Vulnerability data	Exposure data	Risk output
Historical and Projected Climate Data from the regionalized downscaled climate simulation BRIO Project (Leroux et al., 2024) **Historical gridded meteorological data (Leroux et al., 2024)**	Sociodemographic and economic data from the National Institute of Statistics and Economic Studies (INSEE) (https://www.insee.fr/fr/statistiques/6672870) Infrastructure and economic vulnerability data: Infrastructure Public Water and Sanitation Services (SISPEA) Observatory provides annual data https://www.services.eaufrance.fr National centralised data source for understanding the technical, financial, and social challenges of water and sanitation services.	Population: Demographic data from the National Institute of Statistics and Economic Studies (INSEE) (https://www.insee.fr/fr/statistiques/6672870)	Relative Meteorological Drought Risk

Table 1: Data overview workflow #1

8.3.1.1 Risk Analysis Configuration

The relative drought risk workflow was chosen for multiple reasons:

- Data availability.
- Observed drought events, stemming from either a delayed rainy season or dry spells during the rainy season.
- Empirically observed territorial vulnerability, including population, infrastructure (hydroelectric), and agricultural (highly dependent on irrigation).
- Downscaled regional climate projections (Leroux et al., 2024), indicating longer dry seasons and severe drought events on the SWIO.

8.3.1.2 Configuration and Methodology

Climate data: Daily Precipitation [mm], 1981 - 2100, 3 Climate Scenarios (SSP-1-2.6, SSP-2.45, SSP5-8.5) from BRIO (Leroux et al., 2024)

Exposition data: Population data at 200m x 200 m, 2022 snapshot (earlier years available but not used for Phase 1 of CLIMAAX/RISK RA).

Vulnerability data: historical snapshots with availability depending on sources.

- Economic:
  - Low-income rate [%].
  - Poverty rate [%].
  - Price of water service for 120 m³ [€/m³] : Cost of water service per cubic meter, including taxes.
- Social:
  - Share of social housing for vulnerable population [%].
- Infrastructure:
  - Distribution network efficiency [%]: Ratio of water reaching consumers compared to total water introduced into the network.
  - Linear index of network losses (m³/km/day): Measures the volume of water lost per kilometer of network per day.
  - Average renewal rate of drinking water networks [%]: Percentage of the network replaced annually.
  - Soil artificialization [%]: Percentage of soil artificialization

We followed the CLIMAAX handbook but adapted the methodology to our context. This risk analysis was conducted at the IRIS scale ("Îlots Regroupés pour l'Information Statistique" or "Statistical Information Group"), which is commonly used for national statistics including exposition and vulnerability data. Also, the IRIS scale over Réunion Island is spatially coherent with the Climate Data resolution of 3 km by 3km (Figure 2-2).

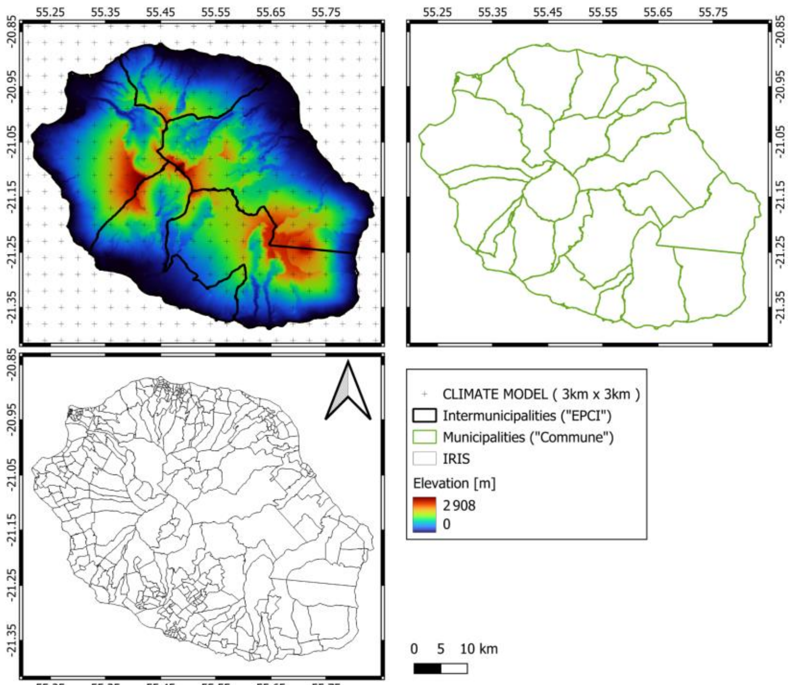


Figure 8-2: Réunion Island Elevation, Climate Model Grid Points and Zoning.

For climate data processing, the steps followed to compute the Drought Hazard Index are as follows:

- Climate data gathering.
- Concatenating historical data (1981 to 2015) with projected data (2015 to 2100), resulting in 3 datasets (1981-2100) for the three SSPs.
- Computing the Monthly threshold.
- Calculating the WASP index at each grid point.
- Assessing Drought Hazard at each grid point following CLIMAAX methodology.
- Aggregation data to IRIS zoning.

As mentioned earlier, the aggregation is applied after climate data processing and drought hazard computation. However, for verification, we plotted a few days with strong regional differences to verify the aggregation function (Figure 2-3). We also plotted an example of Hazard computation on Figure A2 (in SI

For exposure data processing, the steps followed to compute the Exposition Index are as follows:

- Data gathering.
- Aggregating to IRIS scale, if necessary.
- Data Envelopment Analysis.

For vulnerability data processing, the steps to compute the Social (dS), Economic (dE), Infrastructural (dI) and Total Vulnerability Index (dVtot) are as follows:

- Data gathering.
- Aggregating to IRIS scale, if necessary.
- Data Envelopment Analysis for each sub-vulnerability data (dS,dE, dI)
- Total Vulnerability computation: dVtot = dE + dI + dS

Main points of attention:

- For climate data, since we have concatenated the historical part with the projected part before normalization, we can compare the future horizon with the historical period.
- For Infrastructural vulnerability data, the spatial resolution is at communal or intercommunal level, depending on the delegated water services at the time of the sampling. These data are available annually between 2008 and 2023. The indicators chosen in our configuration are plotted per year and per municipality (or intermunicipality) (Figure A3 in SI).
- Future risk projection does not yet consider exposure (demographic changes) and vulnerability shifts. However, these data are available at the regional level for population growth (https://www.insee.fr/fr/statistiques/3254355) or at a finer scale (intermunicipal).

8.3.1.3 Risk Analysis

All the normalised indicators of vulnerability and exposure, along with the aggregated indicators (dS, dE and dI) are plotted in Figure A3 (SI). After successfully computing the Risk Index for the historical period and for the future period (2035-2035 and 2070-2100), we computed the Drought Risk Index Change (%) between the futures period and the historical period. The results are presented on Figure 2-4 for the entire year and on Figure 2-5 for the December-January-February season (DJF). An example of Risk Index results is available in the SI (Figure A3).

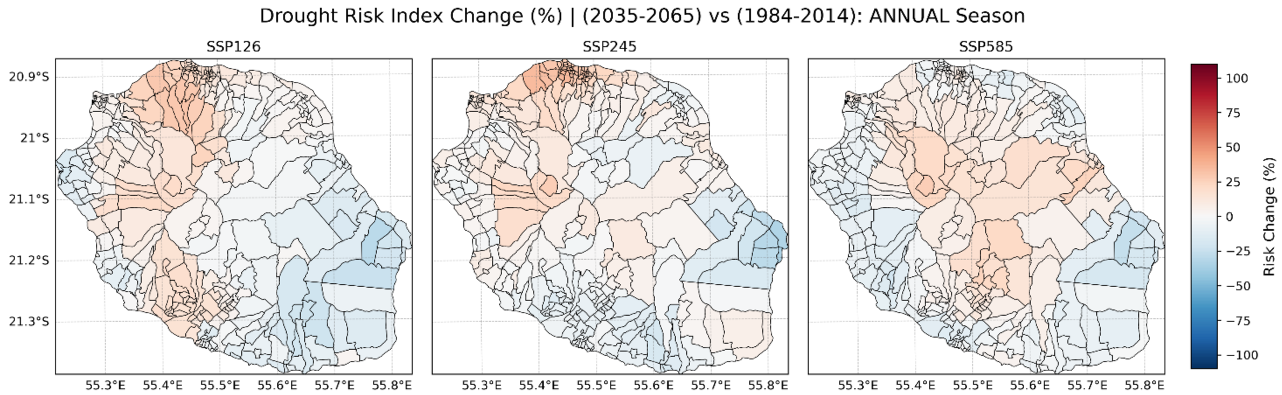


Figure 8-3: Drought Risk Changes (%) between the three scenarios and the historical period considering the entire year.

<u>Annual drought risk changes (entire year):</u>

For SSP-1-2.6:

- Strong increase in drought risk (up to +40%) in the northern and northwestern parts
- Moderate increase in the southwestern and northern eastern part (up to +20%)
- Low to moderate decrease (around -10% to -20%) in the southeastern areas.

For SSP-2-4.5:

- Strong increase in drought risk (up to +40%) in the northern and northwestern parts
- Moderate increase in the western part (up to +20%)
- Low to moderate decrease (around -10% to -20%) in the southern areas.

For SSP-5-8.5:

- Strong increase in drought risk (up to +40%) in central parts of the island
- Modera increase in littoral areas.

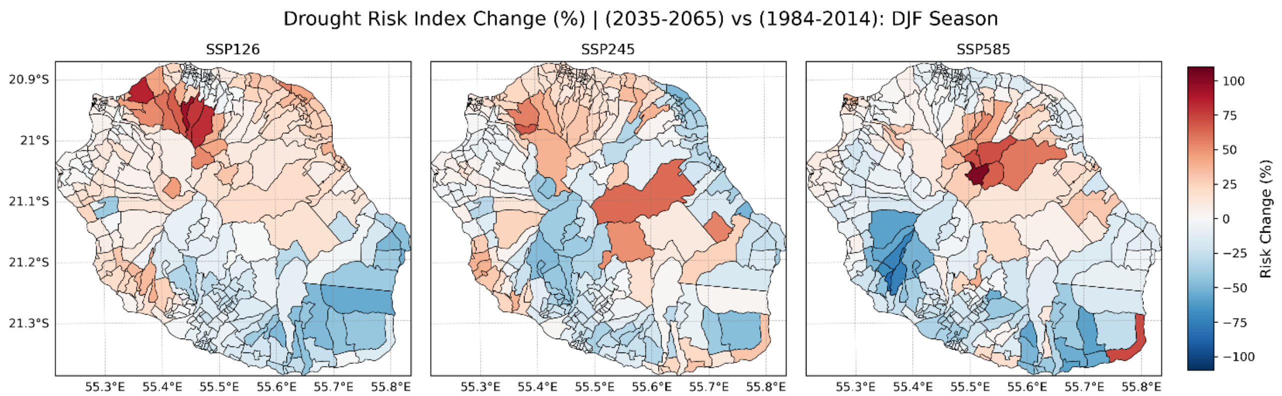


Figure 8-4: Drought Risk Changes (%) between the three scenarios and the historical period considering the DJF season.

<u>Drought risk changes during the critical DJF (wet season onset).</u>

For SSP-1-2.6:

- Very high increase in drought risk (between +50 to +100%) in the northwestern parts
- High increase (between + 40 to +60 %) in the north and eastern parts

For SSP-2-4.5:

- High increase in drought risk (up +50%) in some central parts and spread in localised area
- Moderate increase (+30% to +50%) in the northern parts.

For SSP-5-8.5:

- High increase in drought risk (up +100%) in some central eastern parts.

- Low to moderate decrease elsewhere.

A **significant finding** is the pronounced **heterogeneity** in drought risk across different areas, scenarios, and seasons, complicating overall interpretation. As we have not yet validated these results comprehensively against historical drought events, the current findings should be **interpreted with caution**. Nonetheless, the results clearly underscore the importance of developing **tailored regional and/or sub-regional adaptation measures**, particularly for the northern and northwestern areas, identified as most vulnerable.

8.3.2 Workflow #2 : Heavy Rainfall— Extreme Precipitation

As the secondary workflow, we implemented the risk workflow Heavy Rainfall — Extreme Precipitation risk workflow. This workflow requires climate data and the aggregation of impact data. To do this, we used the data described in Table 2. For Climate Data, we maintained the high-resolution downscaled climate data from the BRIO project used in Workflow #1.

Table 2: Data overview workflow #2

Hazard data	Impact data	Risk output
Historical and Projected Climate Data from the regionaly downscaled climate BRIO Project **Historical gridded meteorological data**	CATNAT event data is sourced from the French governmental database "BD GASPAR" ("Base de Données des Procédures Administratives relatives aux Risques"). This database, maintained by national authorities, contains information on administrative procedures related to natural and technological risks. Crucially, it includes records of "Recognition of the State of Natural Disaster" by National Decree within 30 days of the event. The CATNAT designation triggers a specific insurance regime in France, providing compensation to individuals, businesses, and communities affected by declared natural disasters. The system is based on national solidarity and requires an official declaration to activate claims.	Extreme Precipitation, their evolution and their potential impact on related Natural Disaster

8.3.2.1 Hazard assessment

To define critical impact-based rainfall thresholds, we extracted CATNAT events specifically for Réunion Island. The relevant events within the GASPAR database include, but are not limited to, those triggered by:

- Hydrological Hazards:
  - Flooding due to river overflow
  - Flooding due to runoff and mudflows
  - Flooding due to rising groundwater
- Coastal flooding/submersion
- Meteorological Hazards:
  - Cyclones/hurricanes (high winds, code 1710000)
- other weather related one (code superior to 1700000)
- other natural hazard

Each CATNAT record includes key information such as Affected Area, by municipal code, Event Dates or Hazard Type (See Figure A4 in SI):

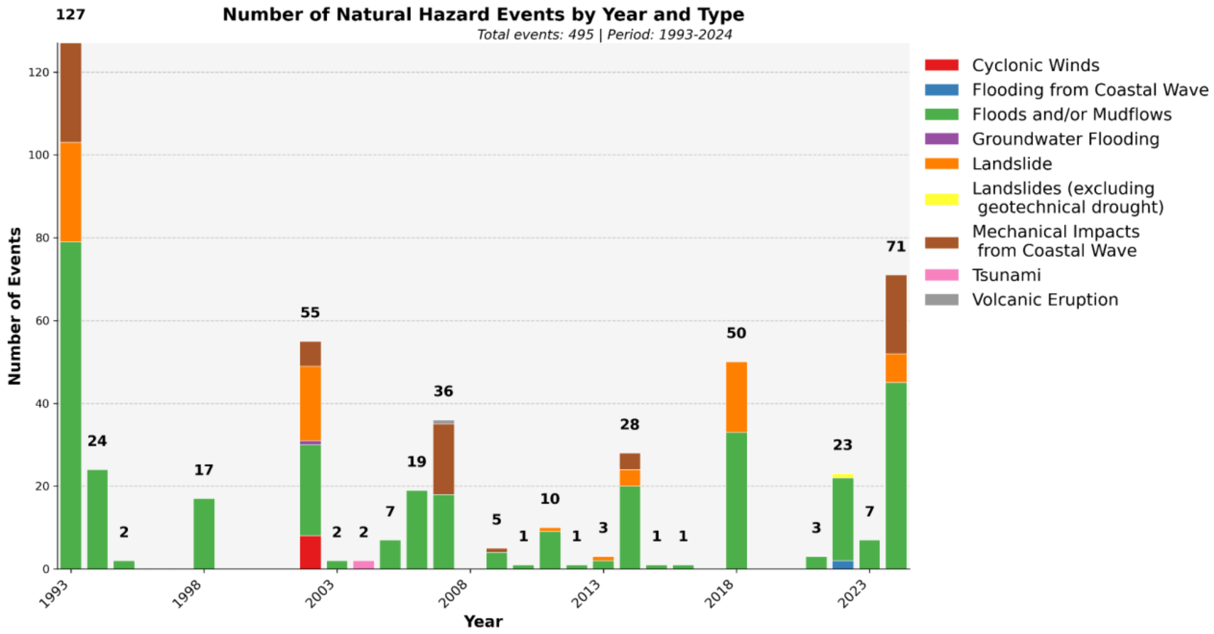


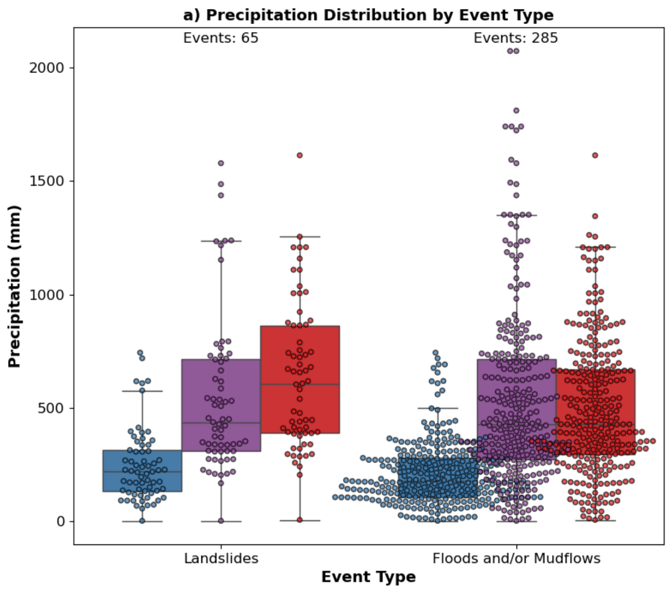
Figure 8-5: Data events timeline for all municipalities of Réunion Island between 1993 and 2024.

We selected "Flooding due to river overflow" and "Flooding to runoff and mudflows" as they are all triggered by extreme rainfall, caused sometimes by the influence of a TC but not systematically. Based on the postal code and the event dates, we linked each event to a daily precipitation measured at the climate data grid point(s) within the corresponding area.

Multiple statistics are then computed:

- Average daily precipitation within the area for the entire event.
- The average cumulative precipitation within the area for the entire event.
- Daily Maximum of Precipitation observed during the entire event across all the area.

The results are presented on Figure 8-6 as boxplot for the two types of events and the three types of statistics, this is further described by their respective statistics with the table on the right side.



b) Precipitation Statistics by Event Type

Metric [mm]	Mean	Median	Max	Q25	Q75
		Landslides			
Daily Avg	247.3	218.3	743.4	132.7	313.7
Avg Cumu	546.4	436.6	1579.2	309.0	713.4
Max Daily	639.6	607.2	1613.8	388.1	863.6
		Floods and/or Mudflows			
Daily Avg	210.1	176.7	743.4	106.6	279.1
Avg Cumu	534.1	428.0	2074.0	271.6	716.0
Max Daily	495.8	427.4	1613.8	295.9	671.2

Metric
- Average Daily Precipitation Observed during the entire event
- Average Cumulated Precipitation during the entire event
- Maximum Daily Precipitation during the entire event

Figure 8-6: CATNAT Data Analysis by events and by metrics

Based on the first metric ("Average daily precipitation over the entire municipality"), we observe that the mean daily average precipitation for landslides is centred around a mean of 247.3 mm, a median of 218.3mm and a maximum of 743.4 mm. For "floods and/or mudflows", these values are approximately 210 mm (mean), 176 mm (median) and 743.4 mm (maximum). While both phenomena seem triggered by similar average precipitation events, "floods and/or mudflows" appear to be associated with lower extreme precipitation (average maximum of 672.2 mm) than "landslides" (average maximum of 863.6 mm). Based on these results, and as a first approach (coherent with Phase 1), we later chose to explore the **threshold of 220 mm/day**, common to both phenomena.

8.3.2.2 Risk assessment

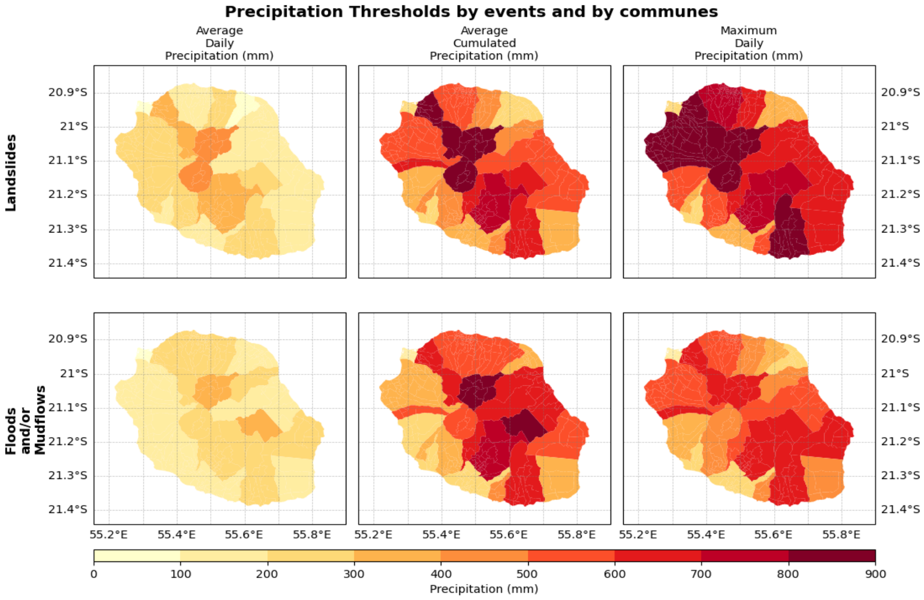


Figure 8-7: CATNAT Data Regional Analysis Results

Since CATNAT data are, by definition, natural disaster and catastrophic events, they are all related to **Major Impacts**. We can now reconstruct a similar table that presented in the CLIMAAX methodology (Table 3). Because we are currently working only with daily data (both historical and projected), the thresholds are computed exclusively for a 24-hour duration.

Table 3 of Threshold: Climate-Impact Database

Location	**High Impact**		**Medium Impact**	**Low Impact**
	Impacts	Threshold		
Regional Average	Flooding to runoff and mudflows	**230 mm in 24h** (based on mean daily value)	To be determined in phase 2 with further collection	To be determined in phase 2 with further collection
Regional Average	Landslide due to Extreme Precipitation	**210 mm in 24h** (based on mean daily value)	To be determined in phase 2 with further collection	To be determined in phase 2 with further collection

The critical impact-based threshold chosen for the regional analysis is **220 mm in 24H**. Following CLIMAAX methodology, we first load the climate datasets and compute the annual maximum time series for the entire year, for the dry season (JJOSON) and for the wet season (DJAMAM). This is done for the 1984-2015 period for the historical data and for the 2070-2100 period for the projection

(Figure A12, SI). As expected, annual maximum precipitation almost always corresponds to the wet season. Therefore, for the rest of the analysis we will not distinguish between wet and dry season and work at the annual scale. This distinction will eventually be explored in Phase 2. As suggested by the handbook, we first looked at accumulated rainfall relative differences. This work was done previously by Lamy et al. 2023 (Figure 5, reproduced in the SI, Figure A14). Notably, this study indicated that changes in precipitation do not show a direct linear relationship with the magnitude of the climate scenario (from an “optimistic” SSP like 1-2.6 to a pessimistic SSP like 2-4.5).

Following the computation of the annual maxima, return periods have been computed, followed by GEV analysis and frequency shifts estimation of selected impact threshold of 220mm/day (interpolated from the return periods). The frequency shifts are presented for three scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) in Figure 8-9 for the mid-term horizon (2035-2065) and in Figure 8-10 for the long-term horizon (2070-2100). We can observe the following results by SSP and by horizon.

<u>For the horizon 2035−2065:</u>

- SSP1-2.6 (low emissions):
  - Clear spatial contrast with increased frequency in eastern regions and decreased frequency (less frequent extreme rainfall) in the western part of Réunion Island.
- SSP2-4.5 (intermediate emissions):
  - Strong increase (up to ~5–10 times more frequent) of heavy rainfall, particularly in coastal northern, eastern, and southern zones.
- SSP5-8.5 (high emissions):
  - Mixed spatial patterns, but overall reduced frequency in the coastal west and north area and slight increases along the eastern coast. Generally, fewer extremes compared to SSP2-4.5.

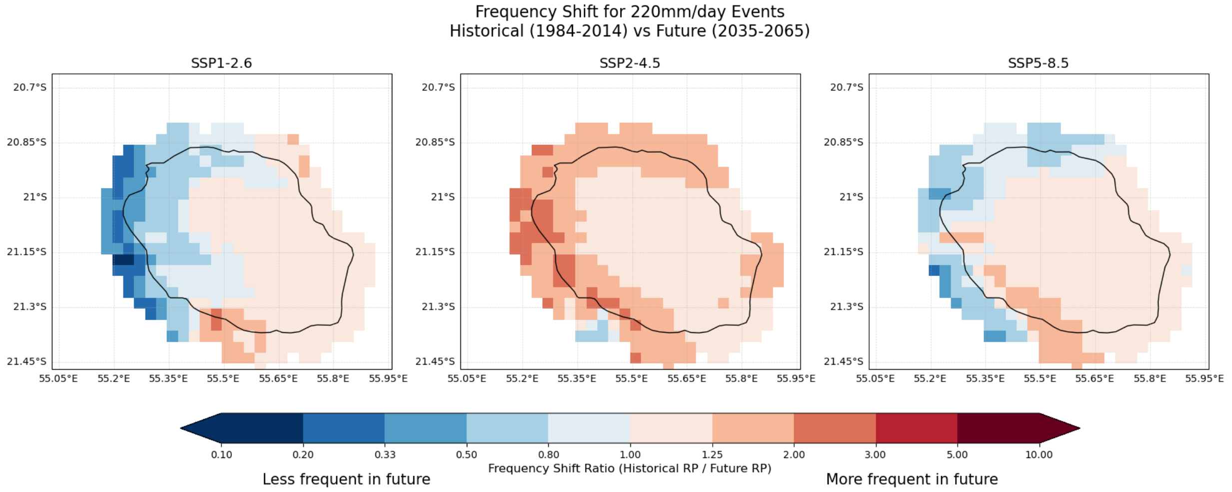


Figure 8-8: Frequency Shifts of High Impact Threshold (220 mm/day) for three scenarios (SSP-1-2.6, SSP-2.4.5, SSP-5.85) in 2035-2065 compared to 1984-2014.

<u>For the horizon 2070−2100:</u>

- SSP1-2.6:
  - Moderate increases of heavy rainfall frequency in eastern-central areas, with decreased frequency in western zones, following a similar pattern to the earlier horizon but more moderate.
- SSP2-4.5:
  - Clear reduction of heavy rainfall frequency in western and northwestern areas, in a complete opposite direction to what is observed in 2035-2065 for the same scenario.

- Slight to moderate increases remain confined to central areas and eastern and southern coastal areas.

- SSP5-8.5:
  - Decrease in heavy rainfall events in the western half.
  - Some isolated eastern coastal areas experience slight increases.

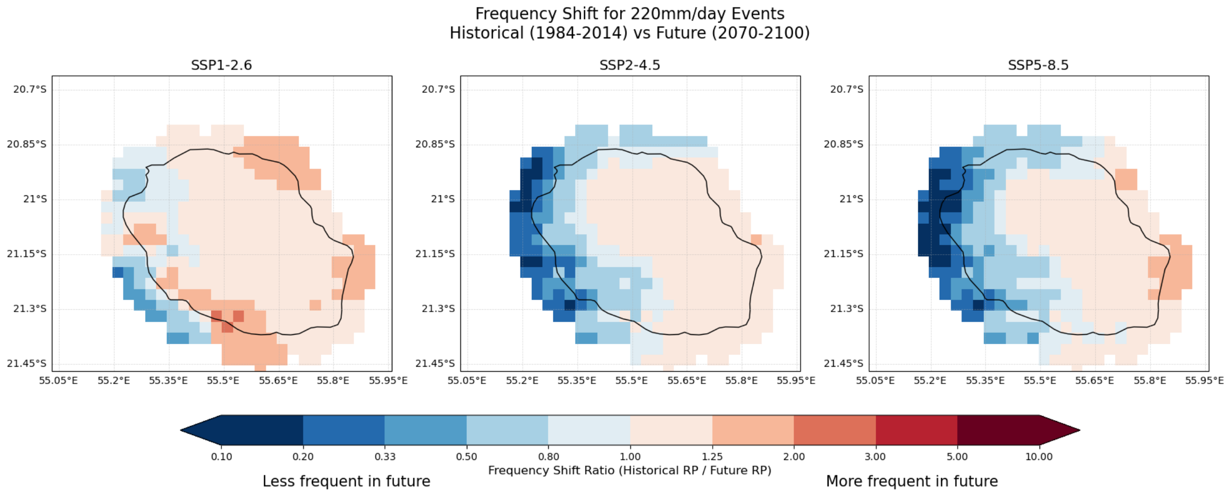


Figure 8-9: Frequency Shifts of High Impact Threshold (220 mm/day) for three scenarios (SSP-1-2.6, SSP-2.4.5, SSP-5.85) in 2070-2100 compared to 1984-2014.

8.3.2.3 Perspective

In the methodology we deployed for phase 1, the impact database only accounts for <u>High Impact</u>. This choice was made for two related reasons: First, the **urgency** and **severity** related to CATNAT events and therefore the priority it has over modere and lower impact. Secondly, the high time needed to gather and consolidate a database of <u>Medium</u> and <u>Low impact</u> which is more diffuse and spread over various documents, not already in a database format but spread out within text articles. One possible improvement is the integration of spatialized thresholds that depend on quantiles of the distribution for each grid point taking better account of the specific climate of the territory. For example, the return period of a daily precipitation event reaching 220mm is estimated to be 50 years at Saint Leu, whereas this value is exceeded several times a year at the station on the volcano.Nonetheless, In Phase 2, we intend to gather additional data from the local knowledge such as press articles or reports but mainly from PPRi and PPRl which contains a history of notable events including dates and location for each commune. This will improve the <u>High impact</u> database and will allow us to construct a <u>Medium</u> and <u>Low impact</u> database.

8.4 Preliminary Key Risk Assessment Findings

8.4.1 Severity

8.4.1.1 Drought Risk

Historically, drought periods have primarily affected the western and northern regions, characterized by prolonged dry spells impacting agriculture, water supply, and biodiversity. Our analysis using regional climate projections indicates an increase in both intensity and spatial extent of drought risk, particularly in the northern and northwestern regions. The scenario SSP1.26 forecasts an increase in drought severity between 50-100% during critical periods (December-January-February), including in the eastern areas. This is coherent with the recently experienced <u>drought event</u> in January to February 2025 in the Eastern part of the island (Figure A5, SI).

8.4.1.2 Extreme Rainfall and Related Hazards

La Réunion experiences some of the highest rainfall intensities globally, leading to significant flooding, landslides, and runoff-induced damage. Historical analysis (CATNAT database) identified a threshold of approximately 220 mm/day, regularly triggering catastrophic events. Projections (SSP2-4.5 scenario) indicate a dramatic rise in the frequency of extreme rainfall events (up to 5-10 times more frequent by mid-century), particularly affecting the coastal northern, eastern, and southern zones. These impacts pose severe risks to infrastructure, human life, housing, and agriculture.

8.4.2 Urgency

8.4.2.1 Drought Risk

Droughts represent slow-onset hazards, with impacts accumulating gradually over months. The increased frequency and severity projected for 2035-2065 mean actions such as enhanced water resource management, infrastructure improvement, and drought-resistant agricultural practices must be initiated promptly. Without early measures, the socio-economic impacts could escalate significantly by mid-century.

8.4.2.2 Extreme Rainfall:

Conversely, extreme rainfall events represent sudden-onset hazards with immediate and catastrophic impacts. Given their rapid onset, urgency for adaptation measures is immediate, as it was recently reminded by the impact of the TC Garance (in. Infrastructure reinforcement, improved early warning systems, flood management, and emergency response protocols require immediate upgrading. Delays in adaptation actions could result in substantial increases in loss of life and damage costs within the next decade.

8.4.3 Capacity

Currently, Réunion Island employs several climate risk management measures addressing both financial and physical resilience.

8.4.3.1 Financial resilience capacity

- French national solidarity mechanisms such as CATNAT insurance and FSOM funds aid post-disaster recovery.
- Recent mobilization of EU funds through the RESTORE regulation following TC Garance highlights existing capacity to leverage significant financial resources for reconstruction and risk reduction. The RESTORE regulation (19 December 2024) provides for part of the programmes ERDF, EAFRD and ESF + to be used for the reconstruction of public assets affected by natural disasters with co-financing rates of 95% and an advance of 25% of eligible expenditure. Following the passage of TC Garance, which devastated La Réunion at the end of February 2025, Réunion Regional Council incorporated the RESTORE amendment into the reprogramming of the ERDF and ESF + 2021-2027 and requested an advance of around €25 million.

8.4.3.2 Social and Human resilience:

- Presence of scientific and operational entities such as OSU-Réunion, Météo-France, and CNRS, providing expertise for risk monitoring and assessment, and such as PIROI for Public awareness and emergency preparedness.

8.4.3.3 Physical and Natural resilience:

- Existing but limited investments in infrastructure resilience, particularly in water and energy networks, and transport routes. However, significant vulnerability remains evident, as illustrated by TC Garance in 2025.

- Efforts are underway for water infrastructure improvements.

Addressing these risks may offers multiple opportunities:

- **Financial:** Enhanced resilience investments could stimulate local economic growth, innovation, and job creation in sectors such as infrastructure upgrades and construction but also in conservation, restoration or renaturation for nature-based adaptation solutions.
- **Social and Human**: Capacity building initiatives can significantly enhance local expertise and awareness.
- **Physical and Natural:** Improved infrastructure resilience can lead to reduced future economic losses, enhanced quality of life, and increased attractiveness of the territory for investment and tourism.

The strategic integration of these opportunities into regional planning (SAR, PPRI, PPRL) can establish a robust and forward-looking approach to climate adaptation and sustainable territorial development.

8.5 Preliminary Monitoring and Evaluation

8.5.1 What was learned?

Conducting the climate risk assessment provided significant insights into regional climate vulnerabilities and risks, particularly highlighting drought and extreme rainfall as pressing concerns. Identifying critical thresholds for hazards (e.g., 220 mm/day rainfall) provided practical benchmarks for impact management and planning.

8.5.2 Difficulties Encountered

Data availability and consistency posed major challenges, especially regarding harmonization across various temporal scales, spatial grids, and entities. The necessity to generate datasets that were precomputed for continental Europe (such as the Drought Hazard Index) was a significant issue and impacted significantly the time spent on the workflows.

Gathering and transforming diverse data types into a common spatial framework was highly time-consuming and resource intensive.

Selecting parameters for optimized vulnerability assessment was challenging and requires further refinement and validation.

8.5.3 Stakeholder Feedback and Next Steps

Stakeholders expressed strong interest and engagement, providing valuable initial feedback on the assessment.

Future phases will involve dedicated working groups to:

- Validate and optimize vulnerability indicators for drought.
- Aggregate and refine impact databases specifically for heavy rainfall.
- Define detailed heavy rainfall thresholds for diverse sectors, including mobility and infrastructure damage.

8.5.4 Data and Research Needs

New research on population vulnerability to drought is critical and currently lacking.

Comprehensive studies analogous to heatwave vulnerability research (Sestito et al., 2025) are necessary to address the full spectrum of hazards relevant to Réunion Island.

9 Conclusions Phase 1- Climate risk assessment

The first phase of the CRA for La Réunion has successfully highlighted critical risks and provided a comprehensive overview of the challenges of understanding climate-related risks facing the territory and planning an adequate adaptation strategy. Through detailed analysis based on high-resolution regional climate projections, the initial assessment has prioritized two main climate hazards: **droughts** and **extreme rainfall events**, each already posing substantial and growing threats to socio-economic stability, infrastructure integrity, public health, and environmental sustainability. This year 2025 was a perfect example of this, with a persistent heatwave during the first's months, a severe drought in the northeastern areas, including water unavailability and water restrictions usages. This was followed by TC Garance, one of the strongest cyclones experienced in La Réunion. With winds gusts recorded at 234 km/h and rainfall of more than 500 mm in 12 hours it generated severe impacts such as flooding, infrastructure damage and destruction. It resulted in 4 deaths, 160 to 200 M€ of damages for the insurance sector based on the CATNAT regime, and 151.6 Millions damage for the agricultural sector. Just after the event, 90 000 houses were without electricity (about 42% of the clients of La Réunion), more than 170 000 peoples were without water. A situation which took a few weeks to recover from.

9.1 Main Conclusions

Regarding the two main risks addressed in this phase, the following preliminary findings are presented; however, because we lack sufficient perspective on the methods and results, these technical conclusions—especially the projections—should be applied with caution.

- Drought Risk: A slow-onset hazard whose severity and spatial extent are projected to increase notably, particularly in the northern and northwestern regions.
- Extreme Rainfall Risk: A sudden-onset hazard expected to intensify, with projections indicating extreme rainfall events becoming more frequent, notably affecting northern, eastern, and southern coastal regions.

9.2 Urgency for Immediate and Strategic Actions:

The nature of these risks, combining slow-onset and sudden-onset hazards, necessitates both immediate interventions and strategic long-term planning. Drought management measures must be initiated promptly to prevent socio-economic disruption and health impact, whereas improvements to infrastructure, rainwater management, urban development and emergency response systems for extreme rainfall events require immediate implementation to minimize potential damage and loss of life and property.

9.3 Data Availability and Methodological Challenges:

Significant efforts were required to harmonize and consolidate diverse datasets across multiple temporal and spatial scales. These challenges underline the importance of continuing efforts to **centralize and standardize regional climate, exposure, and vulnerability datasets for Réunion**, which will e**nhance the efficiency and effectiveness of future assessments** and adaptation monitoring.

The refinement of vulnerability assessment parameters is necessary, involving stakeholders more extensively to develop locally adapted indicators, particularly for drought vulnerability.

9.4 Existing Capacities and Opportunities:

Réunion Island benefits from robust institutional frameworks and financial mechanisms (CATNAT insurance, RESTORE regulation), which currently support disaster recovery and infrastructure resilience investments.

Strong local expertise and scientific institutions provide a valuable foundation for developing effective monitoring, forecasting, and risk management strategies.

Substantial opportunities exist to integrate climate risk management into broader socio-economic development initiatives. Investments in resilience can stimulate local economies, create jobs, and enhance living conditions, presenting a compelling case for **proactive adaptation measure**s.

9.5 Key Findings and Recommendations for Next Phases

Stakeholder Engagement: Positive stakeholder feedback during Phase 1 emphasizes the value of continuing participatory processes. Dedicated working groups should be established to address:

- Validation and optimization of drought vulnerability indicators.
- Comprehensive aggregation and refinement of impact databases for extreme rainfall.
- Detailed sector-specific definitions of critical rainfall thresholds.

Data and Research Gaps: Further research is crucial to improve understanding of the socio-economic impacts of drought, with particular emphasis on human health and social vulnerability. Detailed studies analogous to existing European research on heatwave vulnerability should be conducted for other hazards, tailored to Réunion's specific environmental and socio-economic context.

In conclusion, this initial phase has provided crucial insights into Réunion's climate vulnerability landscape, clearly demonstrating the necessity and urgency for integrated climate adaptation strategies. Subsequent phases will build upon these findings, addressing methodological refinements, stakeholder integration, and targeted analysis, to provide additional information for comprehensive, robust, and regionally tailored climate resilience pathways.

10 Progress evaluation and contribution to future phases

The 1st phase of the RISC-RA project was dedicated to setting up the team's operational organization, establishing the project's governance, making initial contact with the project's external stakeholders and carrying out the scientific work for deliverable no.1.

The climate risks projections for La Réunion produced during phase 1 using "Meteorological Droughts" and "Heavy Rainfall" workflows, will serve as the first version of the Risk Atlas, which will be refined and discussed with local practitioners. The findings of deliverable no. 1 will be used as the basis for the first local workshop to present the RISC-RA project to local stakeholders, such as the Drought Committee, for example.

Since the 1st of October and the launching of the project the main steps were:

Description of the main steps	Connected phases
In November 2024, selection of the scientific team in charge of the Climate risks assessment (through French public procurement process).	**1, 2, 3**
Setting up of the Executive Committee of RISC-RA, which is the main management body for the project and the first stage in the creation of a RPCC for La Réunion.	**1, 2, 3**
1st Executive Committee meeting on 6 December 2024: *reminder of the project context (objectives and milestones) and collective selection of the 2 workflows for deliverable no.1 (Droughts and Heavy Rainfall).*	**1**
Participation of the Director of Research and Innovation of the Réunion Regional council in an **event on Climate Adaptation organized by the Ministry of Higher Education and Research and the Ministry of Ecological Transition in Paris** on 9 December 2024, to present the RISC-RA project as part of CLIMAAX.	**3**
In January 2025, recruitment of a post-doctoral researcher to work full-time on the project as part of the RISC-RA scientific team.	**1, 2, 3**
Workflows application: Identification of usable datasets (including hazard, exposure and vulnerability). Discussion with ECMWF Team concerning the use of local data in spite of Eurocordex data. Risk analysis and first deliverable preparation.	**1**
Contact with external stakeholders holding data and interested in the project work (regional planning agency, National Institute of Statistics, Water Board, French Development Agency, Regional Energy Agency, etc.)	**3**
2nd Executive Committee meeting on 25 February 2025: pres*entation of the Workflows implementation, preparing the 2nd phase methodology, discussing the organisation of the 1st local workshop for local stakeholders to be held in may 2025.*	**1,2,3**

The results of the first phase on KPIs and milestones can be presented as follows:

Table 4: Overview Key Performance Indicators

Key performance indicators	Progress
2 workflows successfully applied on Deliverable 1	***Completed*** - *Preliminary results for* Meteorological *Droughts and Heavy Rainfall Workflows completed for both historical and projection (to be improved in Phase 2 with case studies for the validation of vulnerability indicators and extended analysis heavy rainfall analysis).*

1000 Table 5: Other KPIs impacted during phase 1

Other KPIs impacted during phase 1*	Progress
4 online communications about the project (Regional website, LinkedIn, Region open data portal, etc.)	***25%*** *- 1 communication on LinkedIn following the participation of the Director of Research and Innovation in an event organized by the French Ministry of Higher Education and Research and the French Ministry of Ecological Transition in Paris on 9 December 2024, to present the RISC-RA project as part of CLIMAAX.*
6 Executive Committee meetings with selected scientific and institutional partners in the climate field	***33%*** *- 2 meetings of the Executive Committee have already been organized (December 2024 and February 2025), attended by 10 participants including scientific experts and representatives of the Réunion Regional Council.*
3 dedicated CLIMAAX workshops for local authorities of Réunion Island	***15%*** *- Meetings and discussions with local and national stakeholders to present the project and collect regional data. Preparation of the 1st local workshop (venue, schedule, collective work methodology) to be held in May 2025.*

Table 6: Overview of milestones

Milestones for phase 1	Progress
1st Executive Committee meeting launched	***Completed*** *- 1st RISC RA Executive Committee meeting on 6 December 2024*
1st version of the Atlas of Climate risks projections for La Réunion based on the 1st multirisk assessment	***Completed*** *1st climate risks projections for La Réunion completed using Meteorological Droughts and Heavy Rainfall Workflows outputs*

11 Supporting documentation

List of outputs produced for the supporting documentation:

- Supplementary Information 1: List of relevant figures related to workflow results
- Supplementary Information 2: csv file of a non exhaustive list of datasets over the territory
- Supplementary Information 3: zip file containing pdf files about communication and executive committees Communication Outputs

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