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Coastal risks on the islands of Mauritius and Rodrigues - Synthesis report

Final report

BRGM/RC-74398-FR

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Key words: Coastal Risks, Coastal erosion, Coastal flooding, Cyclone, Sea level, Climate change, Socio-economic stakes, Vulnerability, Perception, Adaptation, Nature based solutions, Mauritius, Rodrigues, Indian Ocean.

In reference lists, this report shall be cited as follows:

GARCIN Manuel, PEDREROS Rodrigo, DESMAZES Franck, LOUISOR Jessie, LE ROY Sylvestre, BONNARDOT François, THIEBLEMONT Rémi, CAPDERREY Cécile, BAILLS Audrey, ROHMER Jeremy, FILIPPINI Andrea, BERNARDIE-TAHIR Nathalie, CERBELAUD Fabien, CHERCHELAY Marie, BOODOO Zyaad (2025) – Coastal risks on the islands of Mauritius and Rodrigues - Synthesis report. Final report. BRGM/RC-74398-FR, 38 p., 19 fig., 3 tab.

Abstract

The coasts of the islands of the Republic of Mauritius is regularly exposed to the hazards of coastal erosion and coastal flooding. The coasts of Mauritius and Rodrigues are home to a large population with many social and economic issues at stake (infrastructures, buildings, tourism, etc.). In the context of climate change and rising sea level, it is important to anticipate their effects on coastal hazards and risks.

AFD (*Agence Française de Développement*) has therefore financed the "*Operational study of coastal risks (coastal flooding and coastal erosion) on the islands of Mauritius (Mauritius and Rodrigues) in the context of climate change*" project (Agreement: n° CMU 1091 01D) whose beneficiary is the Ministry of Environment, Solid Waste Management and Climate Change. The project (2022-2025) is coordinated by BRGM and involves the Indian Ocean Regional Office of Météo France and the Universities of Limoges (Géolab) and Mascareignes.

The aim of the project is to provide maps of coastal erosion and coastal flooding hazards for three timeframes (current, 2050 and 2100) and to assess the associated risks. These maps have been produced on a scale of 1:20,000 and cover the islands of Mauritius and Rodrigues. Three "hotspots" (Flic-en-Flac, Anse la Raie and Port Mathurin), where the stakes are high for the Republic but also representative of the problems encountered, were chosen in agreement with the Steering Committee. In these "hotspots", hazards and risks were assessed on a more precise spatial scale (1:5,000).

This report is the fourth product defined in the project specifications. It summarises all the scientific results produced during the project, in particular the results presented in the phase 2 reports (BRGM/RC-73987, 73988, 73989) and their appendices. Recommendations are then made to improve knowledge of coastal hazards and risks in Mauritius and Rodrigues.

Finally, recommendations are made to: (1) further improve knowledge of coastal hazards and risks in Mauritius and Rodrigues, (2) improve risk awareness (risk culture) and adaptation to coastal hazards, (3) implement a national coastal zone management strategy.

Synthèse

Le littoral des îles de la République de Maurice est régulièrement exposé aux risques d'érosion côtière et de submersion marine. Les côtes de Maurice et de Rodrigues abritent une population importante avec de nombreux enjeux sociaux et économiques (infrastructures, bâtiments, tourisme, etc.). Dans le contexte du changement climatique et de l'élévation du niveau de la mer, il est important d'anticiper leurs effets sur les aléas et les risques côtiers.

L'AFD a donc financé le projet « Etude opérationnelle des risques côtiers (submersion marine et érosion côtière) sur les îles de Maurice (Maurice et Rodrigues) dans le contexte du changement climatique » (Convention : n° CMU 1091 01D) dont le bénéficiaire est le Ministère de l'environnement, de la gestion des déchets solides et du changement climatique. Le projet (2022-2025) est coordonné par le BRGM et associe la Direction Régionale de l'Océan Indien de Météo France et les Universités de Limoges (Géolab) et des Mascareignes.

L'objectif du projet est de fournir des cartes des aléas d'érosion côtière et de submersion marine à trois échéances (actuelle, 2050 et 2100) et d'évaluer les risques associés. Ces cartes sont produites à une échelle de 1/20,000 et couvrent l'ensemble des côtes des îles Maurice et Rodrigues. Trois « hotspots » (Flic-en-Flac, Anse la Raie et Port Mathurin), où les enjeux sont importants pour la République mais aussi représentatifs des problèmes rencontrés, ont été choisis en accord avec le Comité de Pilotage. Dans ces « hotspots », les aléas et les risques ont été évalués à une échelle spatiale plus précise (de l'ordre du 1/5,000).

Ce rapport est le quatrième produit défini dans le cahier des charges du projet. Il résume l'ensemble des résultats scientifiques produits au cours du projet, en particulier les résultats présentés dans les rapports de la phase 2 (BRGM/RC-73987, 73988, 73989) et leurs annexes.

Des recommandations sont ensuite faites pour : (1) améliorer la connaissance des aléas et des risques côtiers à Maurice et à Rodrigues, (2) améliorer la prise de conscience des risques (culture du risque) et l'adaptation aux aléas côtiers, (3) mettre en place une stratégie nationale de gestion des zones côtières.

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List of abbreviations

AFD	Agence Française de Développement
CLR	Coastal retreat also referred as Shoreline retreat
COP	Conference of the Parties
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
Hs	Significant wave height
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LiDAR	Light Detection And Ranging
NBS	Nature-Based Solution
NDC	Nationally Determined Contributions
RCP	Representative Concentration Pathways
SLP	Relative atmospheric pressure
SLR	Sea Level Rise
SSH	Sea Surface Height
SST	Sea Surface Temperature
U	Wind velocity
UNFCCC	United Nations Framework Convention on Climate Change
VLM	Vertical Land Motion
w.r.t	with respect to

1. INTRODUCTION

For several years now, the Mauritian government has been resolutely tackling the problem of climate change. In 2010, the Republic of Mauritius' national communication to the United Nations Framework Convention on Climate Change (UNFCCC) stated that the most significant impact of climate change in the coming years would be the increasing exposure of its islands to natural disasters. According to the World Risk Reports 2017 and 2022, Mauritius is ranked as the 13th country with the highest disaster risk and the 7th country most exposed to natural hazards. The expected effects of climate change are manifold. For example, in coastal areas, tropical cyclones may intensify, heavy rainfall (flash floods) may increase, and the environment may deteriorate (e.g. coral reefs). These changes are linked to a number of parameters induced by climate change, such as the rise in sea level, the increase in sea surface temperature (SST), and the increase in the salinity and acidity of ocean waters. Changes in these factors will increase the exposure of coastal populations and coastal infrastructures to coastal hazards. The impacts on the tourism industry, which is a crucial economic sector for the GDP[1] of the Republic of Mauritius, are potentially very strong. It is therefore necessary to anticipate the effects of climate change, with the aim of ensuring that society adapts in a reasoned manner.

Consequently, the implementation of a disaster risk reduction strategy in the Republic of Mauritius is a key priority for actions to adapt to climate change. The main adaptation measures recommended by the "Nationally Determined Contributions" (NDC) for the period 2016-2030 are as follows:

- strengthening the protection of essential public infrastructure and coastal ecosystems,
- strengthening the protection of coastal zones,
- strengthening water supply security.

As part of the long-term assistance provided by AFD to support the Mauritian authorities and following Mauritius' INDC and COP 21 commitments on Climate Change, Memoranda of Understanding have been signed between the Mauritian government and AFD to operationalize the Paris Agreement.

BRGM (the French Geological Survey) conducted in 2019 a study on the vulnerability of the Republic of Mauritius to seismic and tsunami hazards under a UNDP call for tenders. The results of this study were presented by BRGM in Port-Louis on 19 September 2019 at a validation workshop attended by Mauritian stakeholders. Numerous recommendations were made at the end of the study. These included the need for the Republic of Mauritius to conduct an in-depth study of coastal risks. The Mauritian coastal areas are regularly exposed to the hazards of coastal erosion and coastline retreat and coastal flooding. They are also home to a large population and many social and economic issues (particularly tourism). This is the background to the project: "Operational study of coastal risks (coastal flooding and coastal erosion) on the islands of the Republic of Mauritius in the context of climate change" financed by AFD (Agreement: n° CMU 1091 01D). In addition to the multi-disciplinary expertise of BRGM, which is coordinating the project, the study also relies on the skills of the Indian Ocean Regional Office of Météo-France and the Universities of Limoges (GéoLab) and Mascareignes.

The aim of this project is to provide coastal erosion and coastal flooding hazard maps for three timeframes (present, 2050 and 2100) and to assess the associated risks. These maps have been produced on a scale of around 1:20,000 and cover the islands of Mauritius and Rodrigues. Three "hotspots", where the stakes are high for the Republic but also representative of the problems

[1] Gross domestic product

encountered, have been chosen in agreement with the Steering Committee. In these "hotspots", hazards and risks are assessed on a more precise spatial scale (of the order of 1/5,000).

During the phase 2, three scientific reports have been produced:

- The first volume (BRGM/RC-73987-FR) deals with the forcing factors (cyclones, sea level rise, southern swell) and the methods and tools used to assess and map current and future (2050, 2100) coastal hazards (coastal flooding and shoreline retreat),
- The second volume (BRGM/RC-73988-FR) describes the vulnerabilities and perceptions of different populations and stakeholders to coastal hazards and climate change. It also deals with the assessment of the risks induced by coastal hazards over the three timeframes covered by the project on the coasts of the two islands,
- The third volume (BRGM/RC-73989-FR) examines possible adaptation measures to coastal hazards in Mauritius and Rodrigues in the context of climate change, and more specifically nature-based solutions.

This report summarises the main scientific findings of the project. For each topic covered, the reader is referred to the report that deals with it in greater depth and detail. This report then formulates recommendations and actions to improve knowledge of coastal processes and hazards in Mauritius and Rodrigues. Finally, recommendations are made to improve risk awareness and adaptation to coastal hazards and to implement a national coastal zone management strategy.

1.1 GENERAL METHOD

The general method implemented in this project (Figure 1) is made up of 6 major items that are interlinked. The first is a characterisation of the coastal environment and the processes taking place on the two islands. The second item consists of determining the forcing factors currently acting on the hazard-generating processes and then characterising their evolution for the two future timeframes (2050, 2100). The hazards on the coasts of the two islands over the three-time scales (third item) can then be assessed using field observations and data from various sources, empirical methods and numerical modelling. The fourth item defines and characterises physical and societal vulnerabilities to coastal hazards, future development policy strategies and the spatialisation of assets. By cross-referencing the hazard mapping data with that of the assets, we can carry out the fifth item, which is the assessment of coastal risks for the two islands over three timeframes (i.e. present, 2050, 2100). This assessment is carried out assuming a constant number of assets, which makes it possible to analyse the impact of several scenarios compared with the current situation. The sixth item aims to define the various possible adaptation strategies, based on the potential socio-economic impacts of coastal hazards, and to analyse their advantages and disadvantages. Among these strategies, nature-based solutions are more specifically detailed.

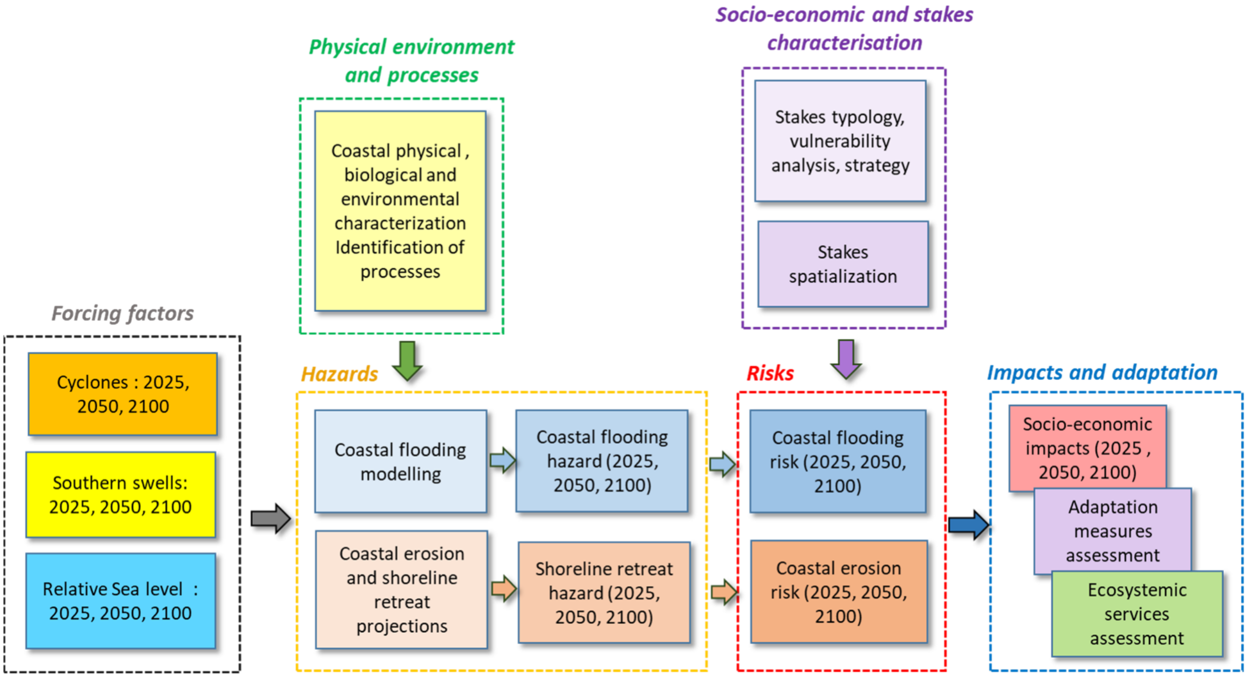

Figure 1: Main tasks and flow chart of the project.

1.2 PURPOSE OF THIS REPORT

The aim of this report is to present in a synthetic form the main scientific results obtained in the project and to propose recommendations for a better consideration of these coastal risks in the development of an adaptation strategy for the Republic of Mauritius.

The report consists of two main parts:

- the main scientific results,
- some recommendations.

In the first part (chapter 2), this report summarises the main scientific results of the project by major themes, such as the forcing factors of current and future (2050, 2100) coastal hazards on the islands of Mauritius and Rodrigues: cyclonic events, meteo-oceanic factors, the evolution of southern swells and future sea level rise linked to climate change (§2.1). The main results of the assessment and mapping (at a scale of 1:20,000) of current and future (2050, 2100) hazards (erosion and coastal flooding) for the entire coastline of Mauritius and Rodrigues are then presented (§2.2.1 & §2.2.2). In three hotspots selected by the project steering committee (Flic-en-Flac and Anse la Raie in Mauritius, Port-Mathurin in Rodrigues), hazard assessment and mapping were carried out at a more detailed scale (1:5,000). Then a section presents the results concerning the perception of coastal risks and climate change by the different actors and stakeholders on the two islands (§2.2.3). The risk assessments carried out on the two islands for the three time periods are then presented (§2.2.4). They allow us to understand, locate and quantify the impact of climate change on coastal risks in the future. An analysis of the different options for adapting to coastal risks in the context of climate change is then presented (§2.3). Particular emphasis is placed on nature-based solutions (NBS) applicable to the coasts of Mauritius and Rodrigues.

The second part of the report (chapter 3) proposes a series of recommendations to improve the quality of data needed to better assess and anticipate coastal risks. Recommendations are then made to improve the organisation and structure of monitoring systems at national level and to improve the anticipation of coastal risks.

2. MAIN SCIENTIFIC RESULTS

In this chapter, we present the most striking scientific results obtained in each task in the form of a 'key message' accompanied by some illustrations of the results. Readers are invited to refer to the phase 2 reports and associated appendices (BRGM/RC-73987, BRGM/RC-73988 and BRGM/RC-73989) for details of the methods, data that have been used and the detailed results obtained.

2.1 FORCING FACTORS

2.1.1 Cyclonic hazard for the present, 2050 and 2100

In order to characterise and analyse current and future cyclone activity (2050, 2100), synthetic cyclone sets have been generated from climate models. From these cyclone sets, wind and pressure fields were generated and then statistically analysed. A comparative analysis of the changes in atmospheric pressure (relative value w.r.t. 1011 hPa) and wind speed induced by future cyclones (2050 and 2080) in comparison with the current climate reveals a decrease of pressure and an intensification of wind speed in Mauritius and Rodrigues, by the end of the 21st century (i.e. 2080-2100) under the RCP8.5 climate scenario (Figure 2, report BRGM/RC-73987). The analysis of extreme values indicates an increase of wind speed ranging from 5% to 10% and a decline in atmospheric pressure of up to 20%. This intensification appears to be more pronounced in Rodrigues than in Mauritius.

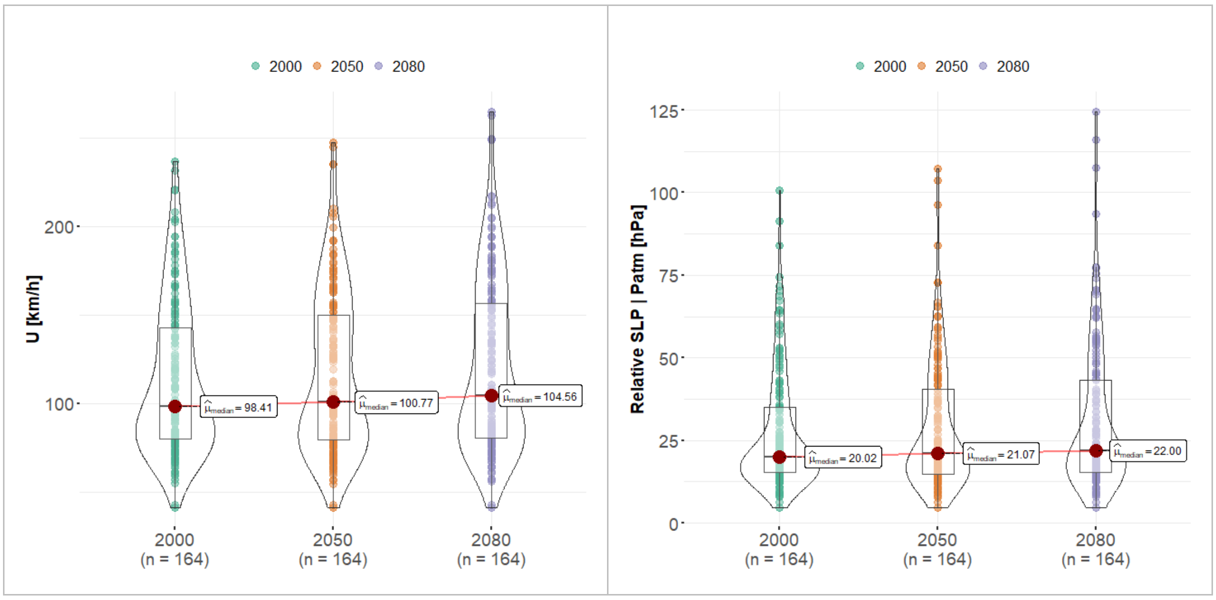

Figure 2: Evolution of statistical quantities (represented in the form of a boxplot and a violin diagram) of the maximum values reached in the zone defined at +/- 2° around Rodrigues. Left: wind speed noted U; right: relative atmospheric pressure noted SLP (compared with the reference pressure 1011 hPa) for different timeframes (2000, 2050 and 2080) under the RCP8.5 climate scenario.

2.1.2 Current and future (2050, 2100) southern swell

Given our current state of knowledge, our analysis (based on a literature review and the analysis of various datasets) suggests no significant change in the intensity or frequency of southern swells in the future in the Indian Ocean including Mauritius and Rodrigues (report BRGM/RC-73987 and Appendix 2).

2.1.3 Extreme values of the meteo-oceanic parameters

Cyclonic forcing data for the present and future have been used to model wave and surge fields in the SW Indian Ocean (including Mauritius and Rodrigues) and to analyse their characteristics. The increased intensity of future cyclones will increase the intensity of meteorological and oceanic parameters (swells, storm surges, etc.) that generate coastal hazards for both Mauritius and Rodrigues (report BRGM/RC-73987). However, this increase remains moderate as the median of the future conditions (Hs,U,SSH) remains in the 95% confidence interval of the present-day conditions (Table 1). Figure 3 illustrates the upwards shift of the return level plot (i.e. increase) for the significant wave height Hs at Mauritius forcing point for present day and future climate scenario.

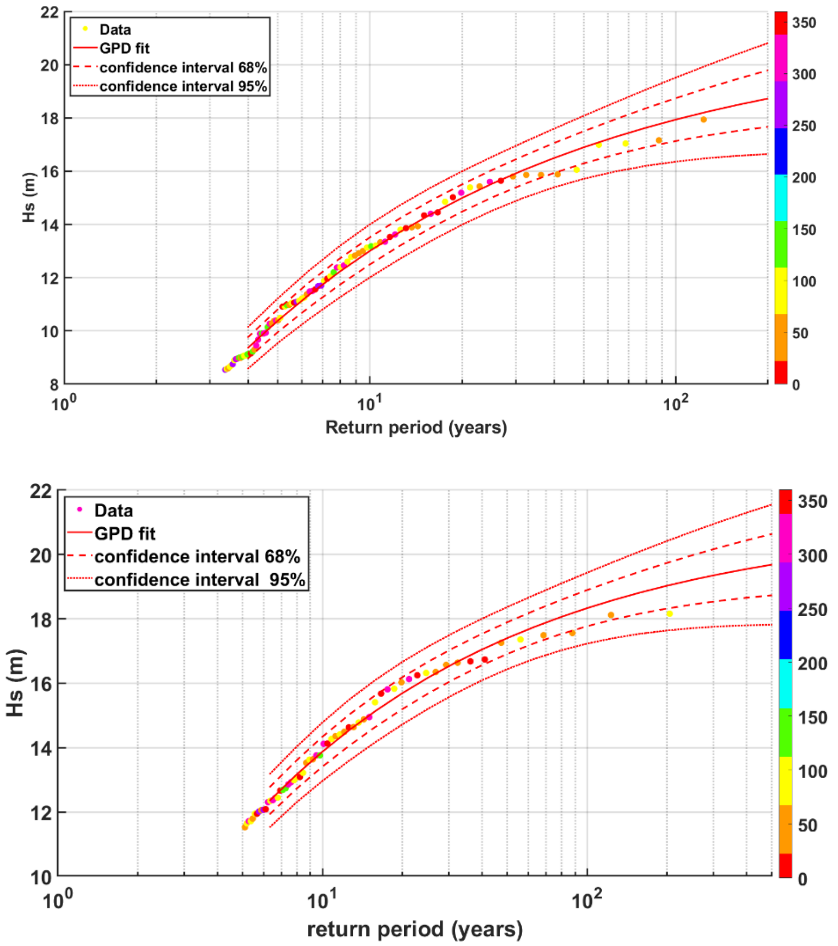

Figure 3: Return level plot for significant wave height Hs at Mauritius forcing point for present day (top) and future (bottom) climate scenario. The points represent the return levels calculated empirically from the data. The curve shows the fit of the statistical model (solid line: best estimate, dashed line: uncertainty envelope at the 95% level estimated by the Delta method). The coloured dots represent the peak direction Dp.

Table 1: 100-year return levels for each meteo-oceanic driver using the univariate probability law for Mauritius (present day and future climate scenario). Numbers in brackets correspond to the 95% confidence interval.

Climate conditions	*Significant wave height* *Hs* (m)	*Wind velocity* *U* (m/s)	*Sea Surface Height* *SSH* (m)
Present day	17.9 [16.35 ; 19.5]	53.2 [49.7 ; 56.8]	0.58 [0.47 ; 0.69]
Future climate (2080-2100)	18.3 [17.2 ; 19.4]	56.4 [52.5 ; 60.3]	0.66 [0.59 ; 0.72]

2.1.4 Assessment of sea level rise in the future (2050, 2100)

Numerous modelling studies on a global scale have been conducted to predict the future evolution of sea levels as a result of climate change, taking into account several greenhouse gas emission scenarios (Table 2). In detail, the SLR is not homogeneous and regional variations are observed. It is for this reason that an analysis of changes in sea level around the two islands has been conducted for multiple climate scenarios up to 2100.

Table 2: Values of relative sea level projections (m) for Rodrigues in 2050 and 2100 with respect to the reference period. The median is shown in bold and the likely range is in brackets.

	2050	**2100**
RCP2.6 (drastic reduction of greenhouse gas emissions)	**0.24** *(0.16-0.31)*	**0.47** *(0.28-0.66)*
RCP4.5 (middle-of-the-road climate change trajectory, with an efficient mitigation of greenhouse gases emissions)	**0.24** *(0.16-0.33)*	**0.56** *(0.36-0.77)*
RCP8.5 (high-emission scenario, where greenhouse gases emissions continue increasing)	**0.26** *(0.17-0.37)*	**0.87** *(0.60-1.25)*
High-end (RCP8.5 with ice-sheet collapse)	**0.44**	**1.84**
VLM (Rodrigues subsidence -2mm/yr)	**0.11**	**0.21**

The rise in sea level will be significant for both islands (Figure 4, Figure 5), especially after 2050 (e.g. in 2100 for RCP8.5: 0.87m for Mauritius and 1.08m for Rodrigues). Our results suggest that Rodrigues could be affected by a land subsidence of -2 mm/year, which would result in an increase rate of relative sea level rise for this island (report BRGM/RC-73987).

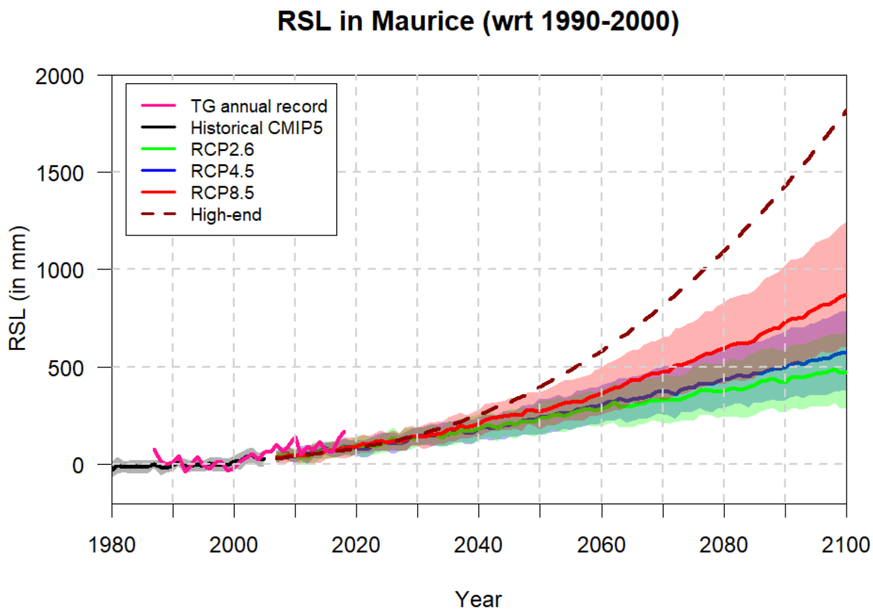

Figure 4: Results of sea-level projections for Mauritius relative to the reference period (1990-2000) for historical reconstruction (black), RCPs 2.6 (green), 4.5 (blue), 8.5 (red) and the high-end scenario (dark red dash). The envelope indicates the likely range (66%-100% probability in IPCC terminology). The pink curve shows the annual average of tide gauge observations.

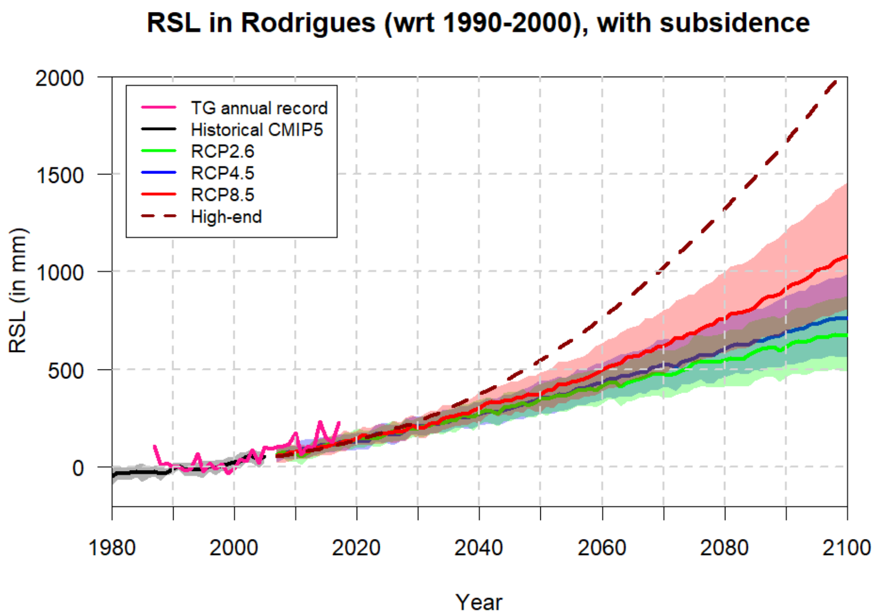

Figure 5: Results of sea-level projections for Rodrigues relative to the reference period (1990-2000) for historical reconstruction (black), RCPs 2.6 (green), 4.5 (blue), 8.5 (red) and the high-end scenario (dark red dash). The envelope indicates the likely range (66%-100% probability in IPCC terminology). The pink curve shows the annual average of tide gauge observations. The additional land subsidence of 2 mm/year is included.

2.2 THE HAZARDS AND RISKS

2.2.1 The coastline retreat hazard for present, 2050, 2100

Beach erosion and the retreat of the coastline are harmful hazards for society. They are likely to increase in the future as a result of climate change, which will lead to an increase in cyclone intensity and a rise in sea level. Significant erosion and coastline retreat have been identified in certain areas of Mauritius and Rodrigues. The causes of this retreat are multifaceted, including both natural and anthropogenic factors, as well as natural phenomena exacerbated by anthropogenic activities.

The coastal retreat hazard has been assessed and mapped for both Mauritius and Rodrigues Islands for 3 timeframes (present, 2050 and 2100). The methodology employed is based on the identification of homogeneous coastal segments (hydro-sedimentary cells and sub-cells) and the formulation of coastline evolution scenarios. Coastline evolution is assumed to be uniform within each segment. The coastline evolution scenarios allow for the formulation of different assumptions for the calculation of the hazard area, based on the available data.

The following parameters were considered in the formulation of the different coastline evolution scenarios:

- Coastal retreat rate, based on data collected during the JICA study (2015),
- Potential retreat caused by a cyclone at the end of the projection period, based on Baird's (2003) modelling and an adapted Fema 540-Square-Foot method,
- Sea level rise and progressive flooding of low-lying areas, based on regionalised sea level rise projections (report BRGM/RC_73987-FR) and 2020 Lidar-derived Digital Elevation Models (DEMs),
- Additional erosion caused by sea level rise, based on an adapted Bruun rule assumption (report BRGM/RC_73987-FR),
- Reduction in coral sediment production by reefs, based on local production estimates from Baird (2003),
- Coastal lithology (sand, basalt, limestone, mixed coastline, etc.), based on the geological map modified for the coastal sector (report BRGM/RC-72793-FR),
- Projected values rounded to the nearest 5 metres.

Three scenarios are used for the calculations.

- The "median" scenario incorporates median parameters, average values, and standard assumptions for the calculations. The resulting potential retreat values are not probabilistic; however, expert judgement suggests that there is a 50% chance that actual coastline retreat will be lower than the estimate, and a 50% chance that it will exceed it.
- The "safety" scenario is based on relatively pessimistic assumptions and potentially maximising parameters, aimed at estimating a shoreline retreat that, according to current knowledge, should not be exceeded.
- Between these two, an "intermediate" scenario is proposed. Its objective is to estimate a retreat trajectory that is less risky than the median approach, without appearing as maximising or pessimistic as the safety scenario.

The projected coastline retreat scenarios were applied across the entire coastlines of Mauritius and Rodrigues. A total of 267 homogeneous coastal segments were studied for Mauritius (Figure 6) and 36 for Rodrigues.

At present, according to the intermediate scenario, the sedimentary coastal segments likely to retreat are estimated to face a retreat ranging between 5 and 20 metres along the coasts of the two islands. Localised retreats of around 5 metres may occur on rocky coasts.

By 2050, areas vulnerable to coastline retreat are projected to face a retreat ranging between 5 and 50 metres, again based on the intermediate scenario. This scenario identifies 61 vulnerable coastal segments where the expected retreat would be between 30 and 50 metres.

By 2100, coastline retreat in Mauritius and Rodrigues is estimated at between 10 and 160 meters, depending on the segment, for the intermediate scenario. Occasional retreats of about 10 metres may occur along basaltic rocky coastlines.

On sedimentary coasts the most frequent retreat for 2100, is projected to range between 55 and 75 metres. The most sensitive zones, representing approximately 25% of the total, are expected to experience setbacks ranging from 80 to 160 metres. These areas are likely to be significantly affected by climate change, depending on the additional erosion factors incorporated into the scenario assumptions.

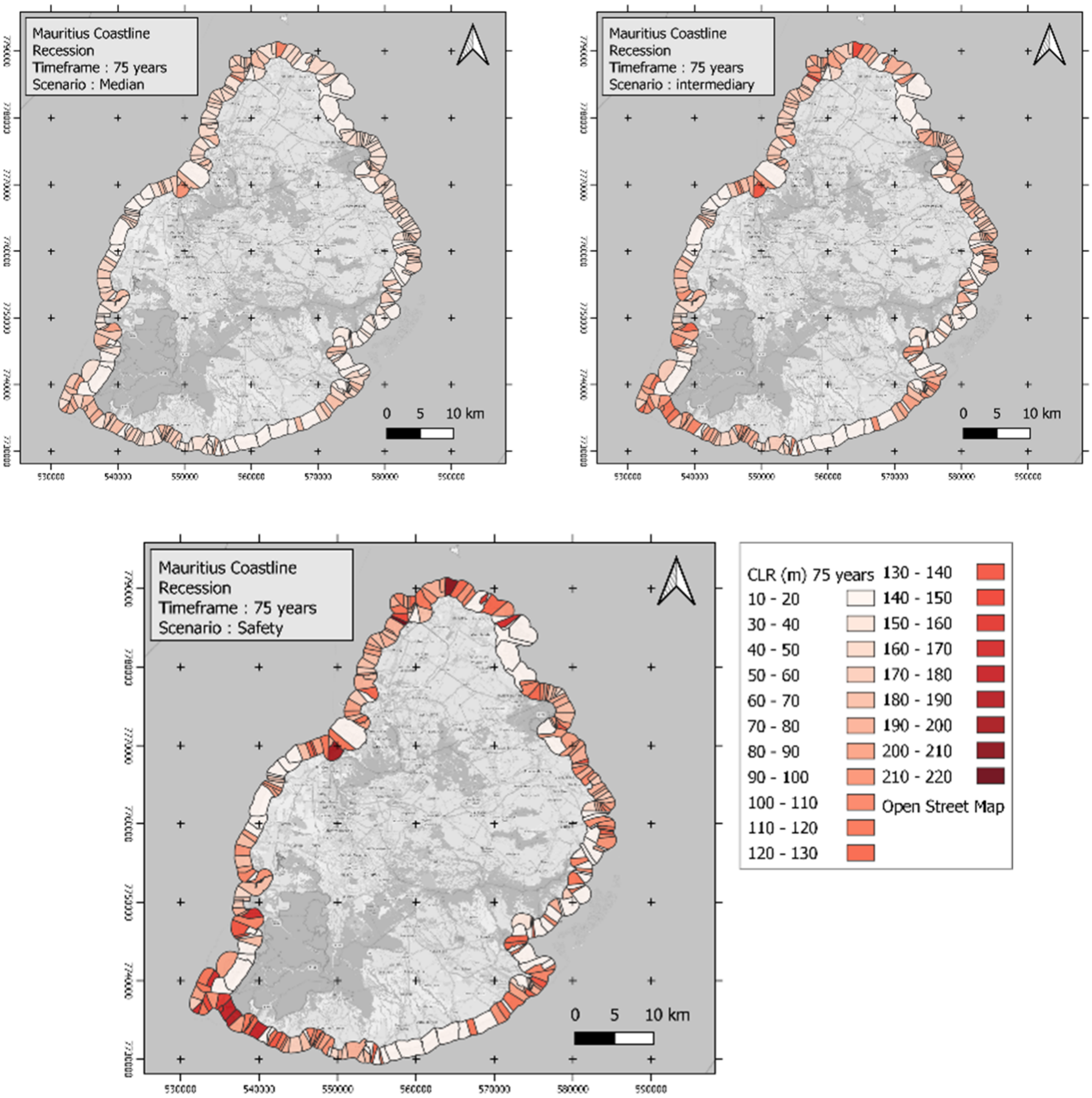

Figure 6: Maps of potential shoreline retreat (CLR) by sediment cell in Mauritius for the 2100 period and the three studied scenarios (top: median & intermediate, bottom: safe).

Maps of exposure to coastline retreat hazards at a local scale (1:10,000 to 1:5,000) have been produced based on estimates of potential retreat values for homogeneous segments across the three timeframes considered in the study (Figure 6).

The detailed maps created for the three hotspots (Flic-en-Flac, Anse la Raie, and Port-Mathurin) allow for visualisation of the extent of areas vulnerable to coastline retreat hazards and the flooding of low-lying zones by sea level rise.

Flic-en-Flac is an area that has experienced significant erosion episodes. As a result, potential coastline retreats due to erosion could be relatively substantial at both future timeframes. These retreats may exceed the regulatory setback of 30 m as early as 2050, according to the safety scenario.

For Anse la Raie and Port Mathurin, no observation or measurement data on coastline evolution is available. Consequently, potential retreat assumptions were formulated based on correspondence with similar homogeneous zones. For these areas, the safety scenario also projects a potential coastline retreat exceeding the 30 m regulatory setback by 2050.

By 2100, coastline retreat due to erosion is expected to be further intensified by sea-level rise and the progressive flooding of low-lying areas. These phenomena could completely transform the landscapes and coastal geomorphology of Mauritius and Rodrigues hotspots, as demonstrated by the intermediate scenarios for Anse la Raie and Port Mathurin, as well as the safety scenario for Flic-en-Flac.

The results of the conducted scenarios demonstrate that in specific regions already vulnerable to erosion, considerable retreats could occur, reaching several tens of metres to a hundred metres by the year 2100 (report BRGM/RC-73987, Figure 6, Figure 7). Although some of Rodrigues' sandy beaches are actually able to recover after a phase of erosion, an assessment of the potential retreat of the coastline shows that retreats could be even greater in certain sectors of Rodrigues than in Mauritius. However, the estimated potential retreat values should be treated with caution due to the lack of data on the historical evolution of the Rodrigues coastline.

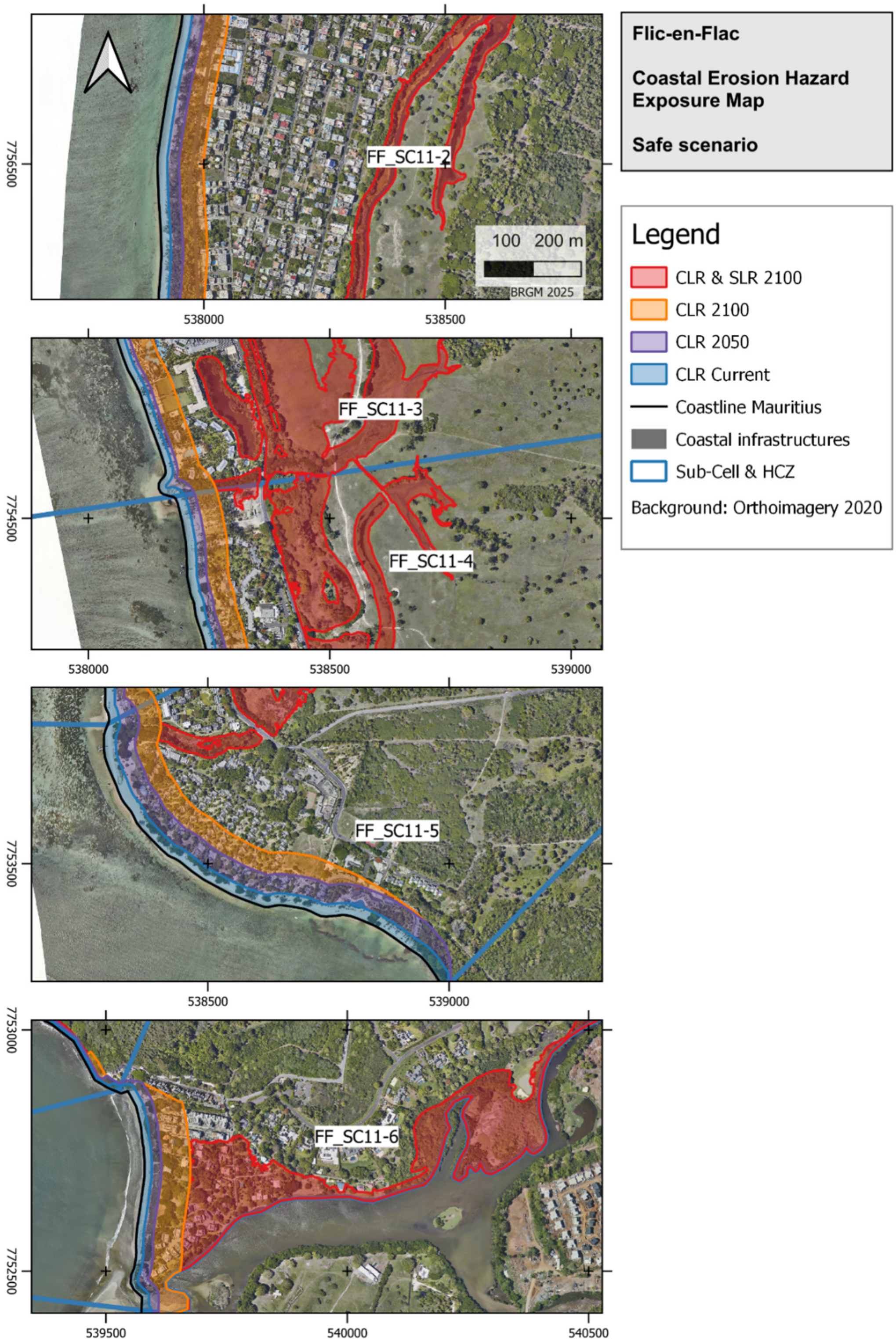

Figure 7: Example of high-resolution coastline retreat hazard maps for 2025, 2050 and 2100, safe scenario. Zoom of 4 hazard-sensitive areas for Flic-en-Flac.

2.2.2 The coastal flooding hazard for present, 2050, 2100

The coastal flooding hazard for the two islands has been estimated using numerical modelling, following a probabilistic approach (100-year joint return period of forcing conditions) and considering the effects of climate change (2050 and 2100 timeframes, RCP 8.5 scenarios) on cyclones (wind fields and atmospheric pressure), waves/storm surge fields and sea level rise. In addition, the local effect of subsidence was considered for Rodrigues.

The main steps of the method are:

a) Generation of two cyclones databases (Mauritius and Rodrigues) for the 3 timeframes (actual, 2050 and 2100) by Météo-France La Réunion which is the Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones for the South-West Indian Ocean. This represents a total of 1,152 events (660 for Mauritius and 492 for Rodrigues) ranging from Moderate Tropical Storm to Very Intense Tropical Cyclone.
b) Wave simulations at regional scale for the current and 2100 timeframes involving:
    - the implementation of 2 models,
    - validation with historical cases,
    - generation of 2 cyclonic wave databases for Mauritius and Rodrigues.
c) Definition of centennial events characteristics
    - extraction of results offshores the 2 islands,
    - joint statistical analysis of waves, storm surges (inverse barometer) and wind.
d) Determination of sea level rise both islands and subsidence for Rodrigues, for the 2050 and 2100 timeframes
e) Modelling the coastal flooding at the scale of the 2 islands and 3 local sites (Anse la Raie, Flic-en-Flac and Port Mathurin) involving:
    - implementation of the models,
    - validation on historical cases thanks to offshore waves, tide gauges and flooding observations,
    - definition of centennial scenarios for the 3 timeframes considering:
        1. tide,
        2. security margin (25 cm) to deal with monthly to seasonal anomalies of the mean sea level,
        3. sea level rise for 2050 and 2100 timeframes,
        4. local subsidence for Rodrigues for the same timeframes,
        5. the choice of 5 cyclones (3 for Mauritius, 2 for Rodrigues) with joint centennial return periods (waves, surge and wind).

The simulation results show offshore significant wave heights (Hs) ranging from 10 to 11 m (south of the two islands) to 15-16 m on the most exposed sides. The peak periods (Tp) associated with these waves vary between 13 and 15 s for Mauritius and 13 and 18 s for Rodrigues. The changes in Hs and Tp between the current climate and 2100 are small, not exceeding 0.5 m and 0.5 s respectively.

The transformation of waves towards the shoreline (propagation/refraction/shoaling/breaking) are strongly controlled by the characteristics of the insular shelf and the presence of reefs.

In Mauritius, where the insular shelf is wider on the N, E and SW sides (coral reefs and shallow lagoons), the waves break between 1 to 5 km from the coast.

It is in these areas, protected from the swell, that the simulated water levels are the highest due to the strong wave setup and greater wind action favouring storm surge (wide and shallow areas). Here, coastal flooding is mainly controlled by overflowing.

Maximum water levels at the coastline exceed 2.5 m already on actual climate reaching maximum values of 3.5 m with on 2100 climate.

The calculated present-day coastal flooding patterns are comparable with the ones obtained for the 2050 timeframe: the flooded area is mostly restricted to river mouth and eastern coastal low lands covered by marshes and forests (especially in the sectors of Pointe d'Esny, Vieux Grand Port, Poste Lafayette, Poste de Flacq, Roches Noires and Poudre d'Or, Anse la Raie), but the seafronts of a few urbanized areas are also affected by the flooding like Roches Noires and Mahébourg (Figure 8). At horizon 2100, however, new large sectors are flooded, including larger urbanized areas like Grand Baie and Mahébourg.

On the western side of Mauritius, characterised by a narrower insular shelf, the calculated coastal water levels are lower than on the other sides of the island, ranging from ~1.2 m today to ~2.6 m by 2100. This leads to flooding by overflowing, which is limited for the present and 2050, but could be significant in 2100 for certain parts of the coast, such as Port-Louis (Figure 9). At Flic-en-Flac, where the insular shelf is particularly narrow, waves break close to the shore on the fringing reef. This leads a coastal flooding by overtopping. Simulations adapted to this type of flooding show that the town centre of Flic-en-Flac could be flooded at the present. By 2050 and 2100, the inundation would spread north and south of the town centre.

At Rodrigues, the waves will break on the barrier reef, reaching Hs and Tp values of 1-1.5 m and 4 s respectively in the lagoon. In general, the scenario produces greater water levels on the south of the island that can reach 2.6 m on actual climate, 3 m in 2050 and exceed 3.6 m in 2100. The largest flooded sectors are at Anse Mourouk, Grand Baie and the urban area of Port Mathurin. However, the extent of inland flooding is controlled by topography, such that it will not increase significantly, but flooded areas will suffer from higher (inland) water levels under future climatic conditions.

The study shows that among the effects of climate change, sea-level rise will have the greatest impact on coastal flooding. This is particularly true by 2100.

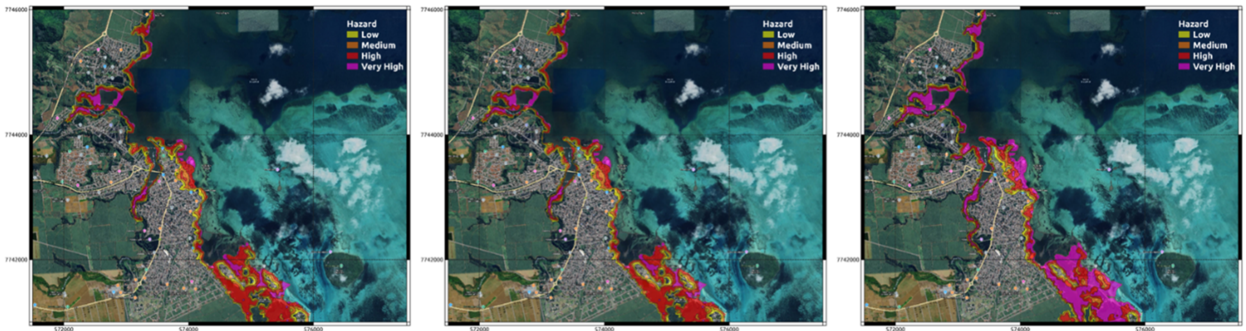

Figure 8: Flood hazard maps for the Mahébourg region under current (left), 2050 (centre) and 2100 (right) climate conditions (RCP8.5).

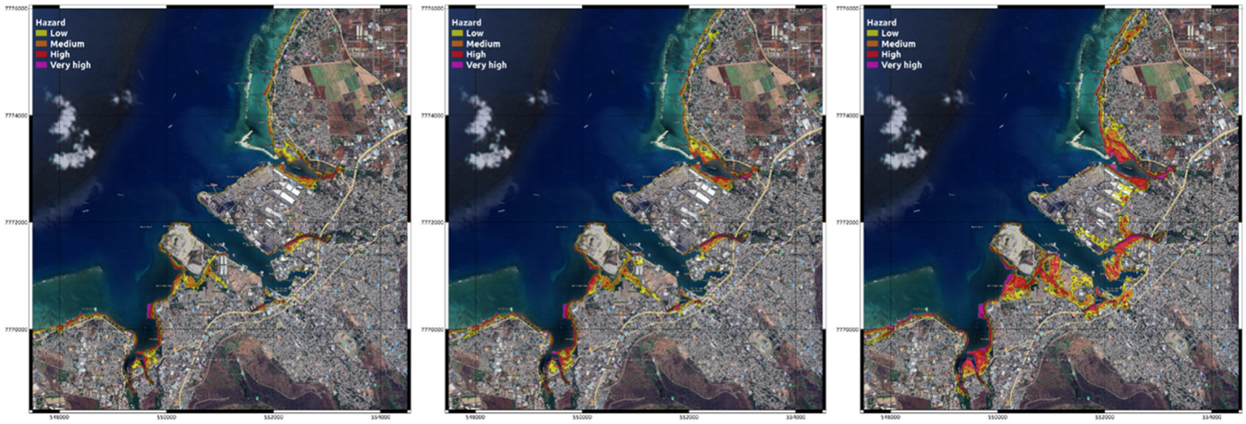

Figure 9: Flooding hazard maps for the Port-Louis area under current (left), 2050 (centre) and 2100 (right) climate conditions (RCP8.5).

2.2.3 Risk perception of stakeholders and potential impact of socio-economic development strategies

Socio-economic vulnerability has been assessed through a quantitative analysis of interviews conducted with stakeholders on the two islands (report BRGM/RC-73988). This was supplemented by an analysis of interviews with local populations for the 3 hotspots (Flic-en-Flac, Anse la Raie, Port-Mathurin).

In Mauritius (Figure 10), analysis of the surveys on the perception of coastal erosion hazard shows a marked discrepancy between the reality of impacted sectors and those identified as such (report BRGM/RC-73988). Some emblematic (or mediatic) sites of erosion and retreat of the coastline, such as Flic-en-Flac, are identified, while others where the level of hazard is comparable do not emerge from the interviews. During the surveys, which were carried out after the passage of cyclone Belal, the sectors of the coast where erosion occurred during the cyclone and which were covered by the media emerged from the interviews; there is therefore a strong bias between perception and reality of the coastal erosion hazard. This bias is even more marked in the case of coastal flooding, as few stakeholders seem aware of the exposure to this hazard.

In Rodrigues (Figure 11), the perception of hazards, whether from coastline retreat or coastal flooding, seems much closer to the reality of the exposure than in Mauritius. The main sectors affected by these two hazards are indeed identified by the people interviewed.

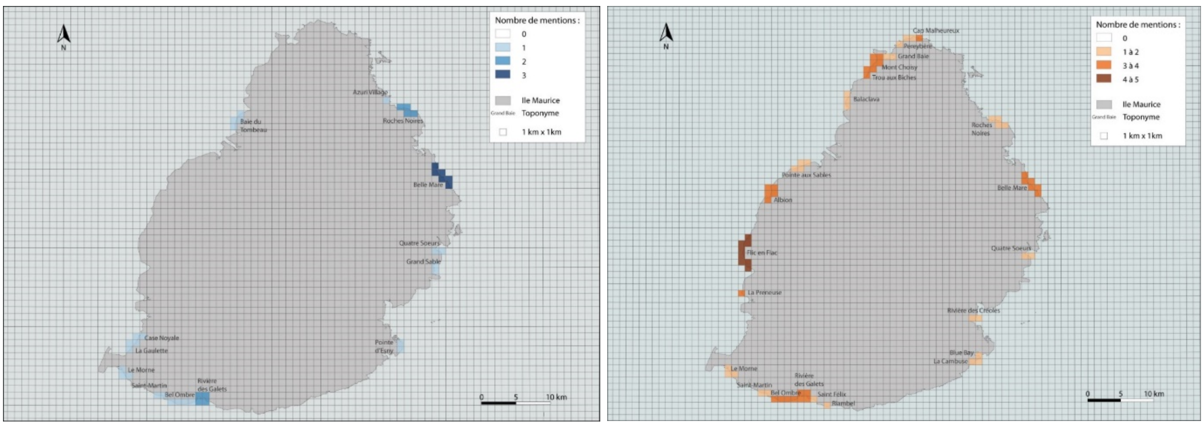

Figure 10: Sites perceived by surveyed stakeholders as exposed to coastal flooding (left), to coastal erosion (right) in Mauritius.

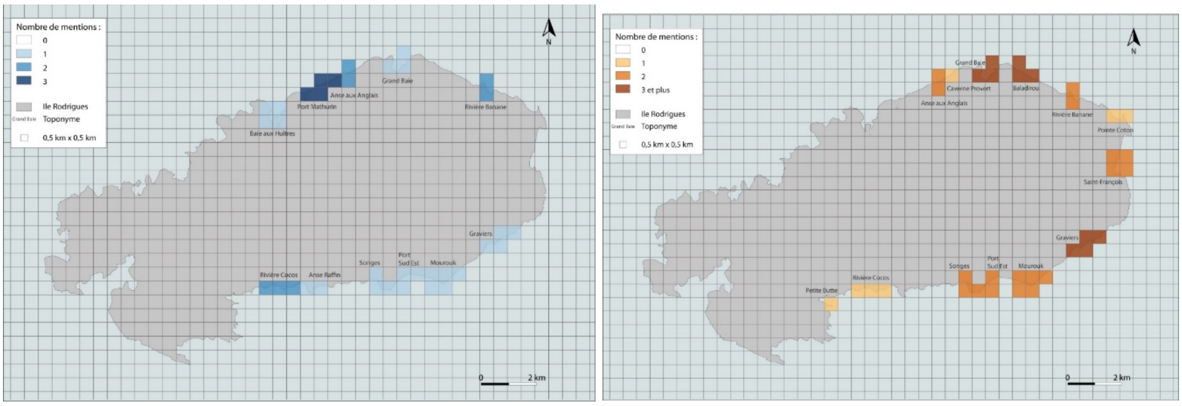

Figure 11: Sites perceived by surveyed stakeholders as exposed to coastal flooding (left), to coastal erosion (right) in Rodrigues.

An analysis of recent historical changes shows the strong development of the coastal zone over the last few decades, particularly in Mauritius and to a lesser extent in Rodrigues. This development is responsible for the presence of numerous assets located close to the coast. The analysis of the future socio-economic development strategies shows that in the short and medium term, the Mauritian government's ambition is clearly to make Mauritius a more attractive destination for international tourists and foreign residents. This will be achieved by significantly increasing accommodation capacity, whether in hotels or in luxury villas and apartments, mainly in the coastal areas most sought after by this clientele, in the Northwest and West of the island. There, sugarcane fields are rapidly retreating in favour of these new housing developments, hotel constructions, and other leisure facilities (golf courses, amusement parks, etc.), mainly concentrated in coastal and pre-coastal areas.

2.2.4 Assets exposed at coastal hazards

A typology and spatialisation of coastal assets has been established. It takes into account various assets relating to tourism, populations, socio-economic activities and more specifically fishing, agriculture, critical infrastructures and tourism. By cross-referencing the hazards with different scenarios and the issues at stake, it has been possible to quantify the risks for the whole of the two islands and at the local level of the hotspots (report BRGM/RC-73988-FR). In some sectors, the impact is very significant, while others are relatively unaffected.

Coastal hazards in Mauritius

Coastline retreat

The number of buildings in the coastal zone of Mauritius, partially or totally affected by coastal retreat and sea-level rise in 2050 is more than 4.000 constructions in the safety scenario (just over half of which is residential, the remainder being hotel buildings). The situation will worsen significantly by 2100 with a loss of nearly 19.000 buildings with around 6,000 hotels and holidays residences impacted (Figure 12).

For the same scenario, the most affected tourist areas are Trou aux Biches, Grand-Baie, Cap-Malheureux, Grand Gaube and the eastern sector (Belle Mare, Trou d'Eau Douce...), the sector or Rivière des Galets, Le Morne, Grande Rivière Noire and Tamarin. The urban sectors of Port-Louis and Mahébourg, which are highly sensitive in both human and economic terms, will be severely affected.

The current buffer zone line of 30 meters is insufficient and unsuitable for the situation for some sensitive coastal sector (e.g. up to 120m in Flic-en-Flac, Figure 13).

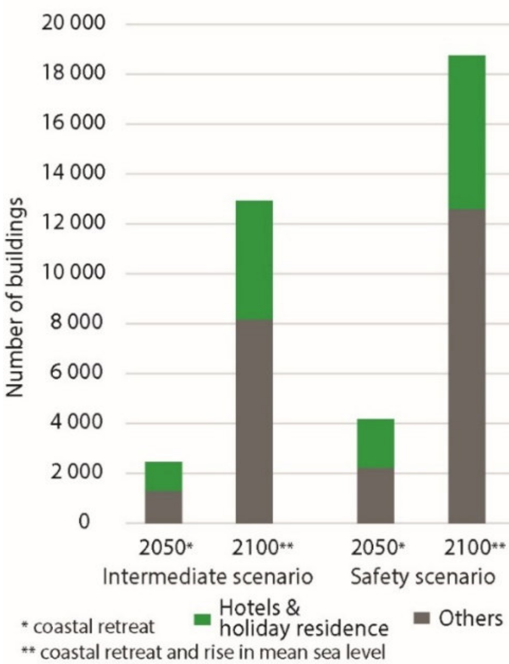

Figure 12: Number of buildings potentially damaged by coastline retreat in 2025, 2050, 2100 for the entire coast of Mauritius.

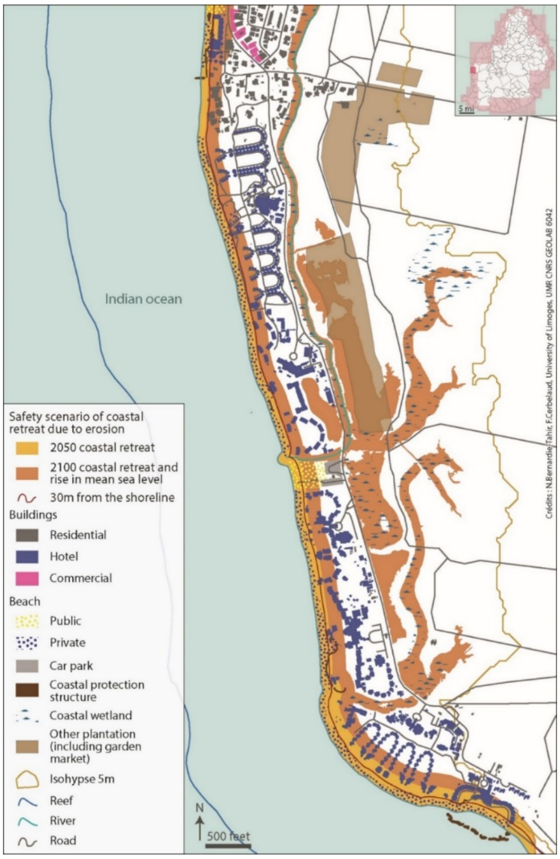

Figure 13: Map of human assets exposed to coastal retreat with the safety scenario at Flic-en-Flac (south).

Coastal flooding

A quantitative assessment of the number of buildings, partially or totally affected by coastal flooding during a centennial event were realized (Figure 14). The first observation is that the impact of coastal flooding is already high today, with more than 13,000 buildings variously affected by coastal flooding. But the risk increases very sharply in 2050 and even more in 2100 with almost twice as many buildings affected, including a significant proportion of hotels. In addition, it should be noted that the hazard level of coastal flooding is increasing by 2100 more than half of buildings will be affected by a “Medium” to “Very High” degree of flooding (see report BRGM/RC-73987 for details about hazard assessment).

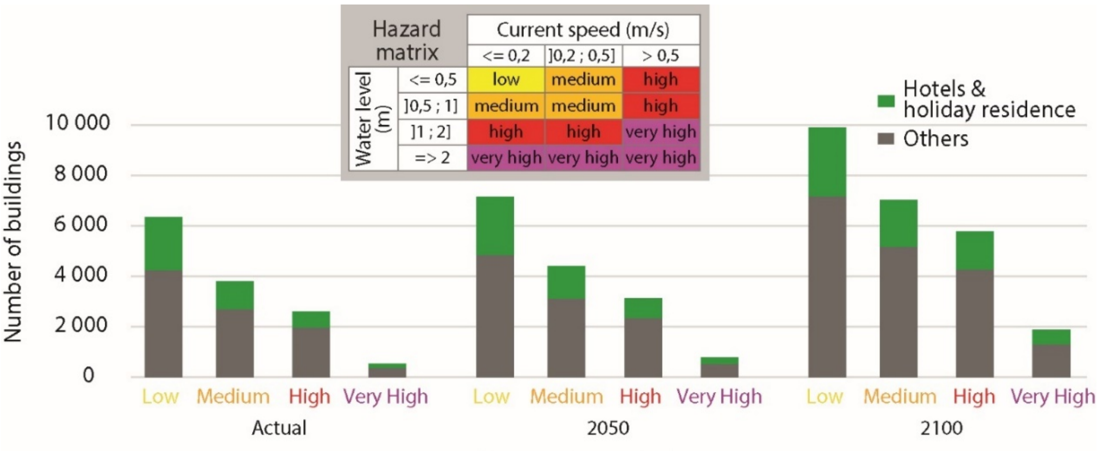

Figure 14: Number of buildings potentially exposed to coastal flooding in 2025, 2050, 2100 for the entire coast of Mauritius.

Coastal hazard in Rodrigues

Coastline retreat

Smaller, less populated and less anthropized coast than Mauritius, with a significant proportion of a rocky coastline, Rodrigues will not suffer the effects of coastal retreat with the same intensity as Mauritius. Port-Mathurin, the port and coastal town where some of the population and activities are concentrated, will suffer the most damage. However, given the island's present limited tourist potential and the small number of hotels on its coastline, the impact on tourism will be fairly limited on an island-wide scale. The potential loss of buildings induced by coastal erosion and sea level rise is therefore fairly limited compared to Mauritius, around 250 buildings in 2050 according to the safety scenario (including very few hotels). In 2100 the loss will be higher around 1,200 buildings, including a tiny proportion of hotels (Figure 15). However, the beaches will be largely affected by the retreat of the coastline, but with fewer assets impacted. Some sectors could undergo major morphological changes to the coast (e.g. Anse Mourouk, Grand Baie).

Coastal flooding

The number of buildings exposed to coastal flooding is much more limited compared to Mauritius. Nevertheless, more than 1,200 buildings could be already affected in 2025, a number which could increase significantly in 2100 with approximately double the number of buildings affected. At this timeframe, the level of hazard affecting the housing will be generally higher than today (Figure 16).

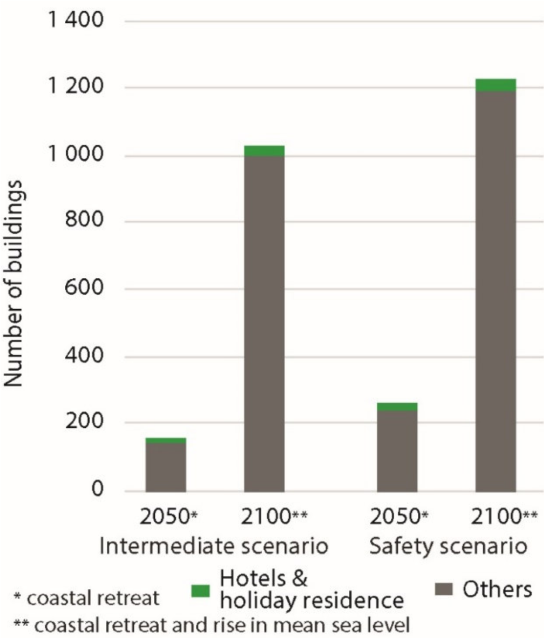

Figure 15: Number of buildings potentially damaged by coastline retreat in 2025, 2050, 2100 for the entire coast of Rodrigues.

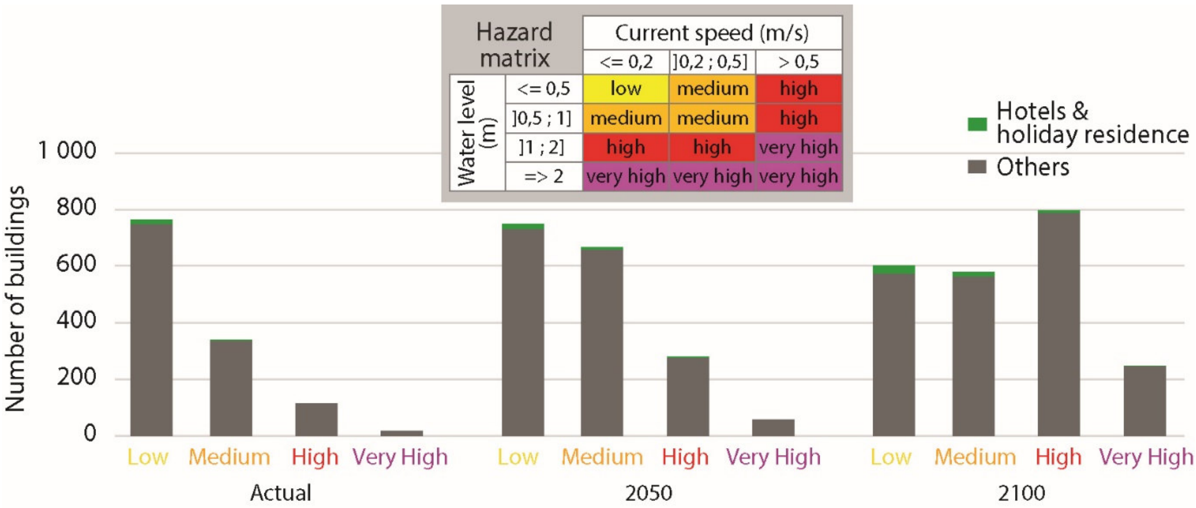

Figure 16: Number of buildings potentially exposed to coastal flooding in 2025, 2050, 2100 for the entire coast of Rodrigues.

Conclusion

Coastal hazards, which will increase in the future due to climate change, will have a greater impact on coastal areas. Reducing their vulnerability in the future will depend on the ability of public authorities to implement a number of appropriate measures that have already been identified. Future vulnerability (2050 and 2100) to shoreline retreat and coastal flooding is high in many areas. The effects will vary from one sector to another, with some putting tourist facilities at risk, others housing and economic sectors, and in some cases strategic energy issues, for example.

2.3 ADAPTATION MEASURES TO CLIMATE CHANGE AND COASTAL RISKS

2.3.1 All measures

The proposed assessment focuses on how adaptation measures address changes in risk and reduce existing vulnerabilities for Mauritius and Rodrigues. The assessment method of adaptation measures consists of comparing 56 selected measures (Figure 17) with anticipated changes in natural hazards, based on 12 criteria such as, for example, reversibility and robustness. The aim of this approach is to provide decision-makers with a ‘toolbox’ for iterative long-term adaptation planning (report BRGM/RC-73989-FR).

The analysis (Figure 18) reveals that most adaptation measures are rated positively against six of the twelve qualitative criteria, with nature-based solutions generally receiving the most favourable assessments. These solutions are particularly flexible/reversible, they provide co-benefits, and they notably improve ecological capacity and resilience. On the other hand, measures related to built infrastructures and technology often receive fewer positive assessments and are criticised in particular for being less flexible. Socio-institutional measures, on the other hand, are less affected by local conditions and perform well regarding robustness, although they do not provide ecological co-benefits.

Categories	Sub-categories	Adaptation measures
Marine and coastal Nature-Based Solutions (NBS)	Actions on reefs	Creation or restoration of oyster reefs
		Creation or restoration of coral reef
		Artificial coral reefs
	Actions on vegetation	Creation or restoration of wetlands
		Creation or restoration of Mangrove
		Creation or restoration of seagrass meadows and seaweeds
	Management	Protection of coastal ecosystems: e.g. trampling limitation on coastal dunes and cliffs
		Establishment of marine protected areas - Protection of coastal marine ecosystems: reefs, seagrass beds, seaweed beds (management of visitors, pollution control, etc..)
	Actions on dunes	Sand trapping (Sand fences, windbreaks nets, branches)
		Dune reconstruction or profiling
		Dune revegetation
	Actions on cliff	Cliff revegetation
Built infrastructure and technology	Technology	Establishment of a coastal monitoring / observation network
		Creation or improvement of early warning systems
	Actions on beach	Beach nourishment / reprofiling
		Beach Drainage
	Actions on cliff	Reprofiling of rocky coasts
		Cliff drainage
		Anti-runoff and anti-infiltration devices at cliff top
		Bolting/pinning
		Concrete buttresses and riprap strips
		Reinforced geogrids and pinned nets
		Cliff foot palisade
	Coastal structures	Installation of protective structures in natural materials - Use of geotextile
		Abandonment / removal of existing defences
		Temporary defences
		Temporary storm surge dams - - Installation of retractable barrier systems in estuaries
		Adjustment/increased height / creation of hard engineering structures
		Second line levee / dyke
Socio-institutional adaptation	Management and legislation	Limiting action liable to cause subsidence
		Legislation: Adoption of building standards adapted to hazard exposure
		Integrated coastal zone management, regional harmonization and sharing of best practices
	Crisis management	Implementation of municipal and regional plans for crisis management
	Increasing knowledge and communication	Hazard and vulnerability mapping
		Education: training dedicated to risks and climate change
		Communication through medias
		Raising awareness / informing populations affected by risks
		Scientific communication through conferences and research network
		Climate services
		Concertation and co-construction of adaptation measures
	Urban planning and related measures	Implementation of land management programs (land exchanges)
		Integration of climate change and its effects on coastal hazards in urban planning and documents
		Avoid building in hazardous areas
		Strategic retreat

Figure 17: Adaptation measure analysed.

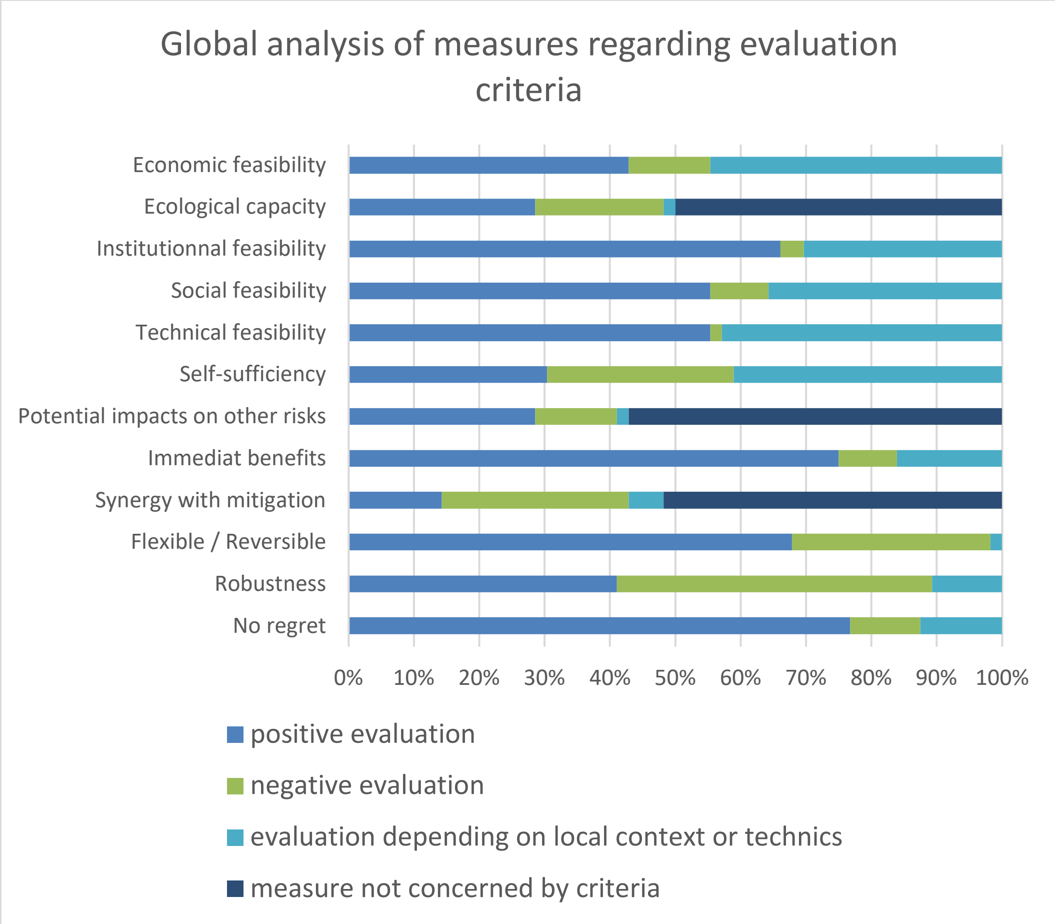

Figure 18: Global analysis of adaptation measures regarding the 12 evaluation criteria.

2.3.2 Nature based solutions

An analysis of the potential for applying Nature Based Solutions (NBS) to reduce hazards and adapt to climate change was carried out in Mauritius and Rodrigues. Based on available data, a sectoral analysis of the two coastlines was carried out (24 sectors for Mauritius and 6 for Rodrigues). This analysis was designed to determine the type and state of the ecosystems present on each stretch (Figure 19), the level of artificialisation and anthropisation of the coastline and the other pressures that the ecosystems are exposed to (Table 3). The overall level of investment in ecosystems (monitoring, protection, restoration) has also been qualified. This study (report BRGM/RC-73989) shows that the coasts of Mauritius, and even more those of Rodrigues, can benefit from NBS approach in certain sectors.

Among the 24 sectors considered in the study, the island of Mauritius offers significant opportunities for the implementation of NBSs, in particular through the restoration and protection of coral reefs coupled with meticulous management of direct anthropogenic pressures (report BRGM/RC-73989). However, this action should not be considered in isolation, but in relation to the potential synergies that can be achieved with other ecosystems. There are a number of factors that may promote the implementation of these solutions, such as the strong commitment of communities and NGOs, the existence of sectors where the management of anthropogenic pressures can be envisaged, and the significant level of scientific knowledge that now exists about these ecosystems. In particular, the perception and acceptability of NBSs by decision-makers and the general public must be integrated into the planning process. NBSs are not necessarily solutions to be implemented as a first solution, particularly in sectors where the stakes are strategic and unmovable or where development time is too long given the urgency of the situation. On the other hand, all development must consider the possibility of allowing ecosystems to function in order to obtain maximum co-benefits that are sometimes not guaranteed by hard, heavy engineering or even hybrid technologies and structures (e.g. carbon storage, water purification, food supply, biodiversity etc.). The irreplaceable nature of these ecosystems must be taken into account. In addition, the availability of recently developed tools makes it increasingly possible to guide actions to restore, manage and protect these ecosystems (guides on the ecological restoration of mangroves, reefs and seagrass beds assorted to a significant amount of feedbacks), as well as to compare the effects of actions carried out in several places over a number of years.

Regarding Rodrigues, implementing NBS actions in the six sectors is not only an opportunity but also a necessity to enhance coastal ecosystem resilience against climate change challenges and ensure ecosystem services at the island scale (in particular food supply and protection). The whole island offers a great potential thanks to its natural capital still preserved (but under threats). The restoration and protection of mangroves, seagrass meadows, and coral reefs are key levers for mitigating erosion and flooding hazards while supporting local biodiversity. However, these initiatives must be accompanied by sustained efforts to manage coastal artificialisation, reduce pollution, and control invasive species to ensure the long-term success of these natural solutions.

Figure 19: Example of typical ecosystems existing on the coasts of Mauritius and Rodrigues (from top to bottom and from left to right): seagrass beds, tidal flat and mangrove, coral reef, sandy beach and dune.

Table 3: Elements evaluated for each sector of the coasts of Mauritius and Rodrigues to assess the potential for applying nature-based solutions (NBS) to reduce risks and adapt to climate change.

Main criteria	**Content**
Anthropogenic pressures and the condition of ecosystems present within the sector	- Main anthropogenic activities and pressures associated, and the level of artificialisation - Ecosystem diversity: assess the variety of ecosystems present in the sector, including their interconnections and how they can complement each other for effective protection. - Ecosystem exposure to pressure(s), their vulnerability and their ability to recover from disturbances (e.g. bleaching events, pollutions, etc.)
Manageability of pressures	Analysis of pressures on the ecosystems including tourism and urbanisation, and assess whether they are manageable within the technical, social, and institutional feasibility.
Reef dependency level	Determine the degree of reliance on reef ecosystems in terms of physical protection.
Coastal erosion and flooding hazard intensity	Coastal erosion and flooding hazards represent critical threats to shorelines, especially in the context of rising sea levels and extreme events intensified by climate change. Each sector is assessed for its exposure and vulnerability to erosion and flooding processes.
Historical context and protections currently in place	This criterion includes the rate of the sector's coastline artificialisation in the area as well as the type of artificialisation present. This aims to draw attention to potential more natural solutions, particularly the proportion of artificially altered coastline without protection objectives. The criterion also includes the existing actions (if available, e.g initiatives related to adaptation, protection, and restoration that could support the implementation of nature-based solutions) and the institutional support (i.e. consider the existing institutional framework and its capacity to support the implementation of nature-based solutions in the sector).
NBS potential for hazard mitigation / NBS implementation After compiling data on these elements, each sector is assessed in terms of its potential for hazard mitigation. This section aims to evaluate the ease of NBS implementation, categorizing the potential as: - To strongly consider, - To be considered and analysed according to sector margins, - Not to be excluded but complex as first resort. Indirectly all criteria give an insight for combination opportunities (in other words identify combinations of ecosystems such as seagrass beds and mangroves or seagrass beds and reefs that could enhance resilience and protection), institutional support facility to support, implement and develop more NBS actions.	

3. RECOMMENDATIONS TO IMPROVE CONSIDERATION OF COASTAL HAZARDS AND RISKS AND ADAPTION TO CLIMATE CHANGE

This project has produced results, assessments and hazard and risk maps that constitute a knowledge base at the time of the project. In the current changing context, where climate change and pressures from human societies play a major role, the current state is only temporary. This is even more true for coastal risks, where assets on the coast will change depending on the choices made in development and adaptation policies.

As part of a risk prevention policy, it is therefore necessary to continue efforts to improve the assessment of hazards and risks and to update the knowledge data. This involves:

- Scientific monitoring of developments in knowledge and forecasts of climate change and its impact on the forcing factors of hazard generating phenomena,
- At national level, by improving knowledge and local data.

3.1 IMPROVING KNOWLEDGE AND DATA

There is a large amount of data on Mauritius and Rodrigues that has made it possible to carry out this project. This data is held by a large number of organisations with different prerogatives in relation to the coast. This made the data difficult to collect and it is also a difficulty for carrying out an integrated project such as this one. With regard to the existing data, we found a number of shortcomings that sometimes affected the quality of the project's outputs. For example, the existing data very rarely had metadata providing information on the date of acquisition, the acquisition methods, the operator, etc. In addition, some of the data would have required and benefited from regular updating. Another key issue with the data is the accuracy of data geolocation: some of this data has obviously incorrect or inaccurate geolocation information while the accuracy of data geolocation is essential for any spatial processing.

In addition, we faced the problem of the inaccuracy of the LiDAR in Mauritius, which shows errors and inconsistencies in the elevation values, especially in the low-lying areas of the coastal fringe (report BRGM/RC-72793-FR). This type of error has a significant impact on the flood modelling and the related assessment and mapping of the risk of coastal flooding. In fact, these errors lead either to an overestimation of the flood risk if the LiDAR heights are lower than reality or, conversely, to an underestimation of the risk if the LiDAR heights are higher than reality.

There are several actions that could usefully be undertaken to improve the assessment and mapping of coastal hazards and risks. For example, it would be desirable to acquire additional bathymetric data in areas not currently covered, particularly in the shallow waters of the Mauritius and Rodrigues lagoons. This additional data would make it possible to refine the modelling of waves and storm surges along the coast and flooding on land.

It would be also beneficial to carry out long-term (permanent) monitoring of changes in the reference topographic profiles of beaches and the coastline as a whole. In the past, some topographic profiles were established as part of studies or projects but were abandoned as soon as the projects were completed. This lack of continuity in monitoring is detrimental, for example, to assessing the dynamics of coastal erosion and shoreline retreat.

Another useful acquisition would be the systematic monitoring of the position of the coastline on each island. Ideally, this monitoring should be carried out at a constant frequency (annual and/or seasonal) and after a major meteorological or oceanic event (such as cyclones or episodes of southern swell) in order to measure the impact. It would also be useful to define an official coastline for the two islands, based on a recognised indicator. This reference coastline should be updated very regularly and be used as a reference both for the monitoring of the coastline by local authorities and for the analysis of erosion and coastline mobility. Such data on changes in the position of the coastline would allow to refine the knowledge of the impact of weather and sea events (cyclones and southerly swells) on the morphological evolution of the coastline.

Long term monitoring of ecosystems (qualitative and quantitative approaches) and the physico-chemical conditions of their environment in several representative sections of the coastline of each island would be useful to better define the health of these ecosystems, detect any changes in their functioning and to monitor changes under both climatic and anthropogenic pressures. Similarly, any action taken to reduce hazards, whether through engineered solutions or NBS, would benefit from regular monitoring to analyse its impact on the physical coastline as well as on ecosystems and populations. This would provide specific feedback for the two islands that would be useful for future projects and adaptation strategies.

During the present project a geo-referenced database of structures that interact with coastal dynamics was created (Appendix 1 of report BRGM/RC-73989). Knowledge of coastal structures is essential for assessing the level of protection they provide, their reliability, and the disturbance they cause to cross-shore and longshore dynamics and ecosystems. This database reflects the state of knowledge at the time of this project and should be completed and corrected as necessary, but above all it should be regularly updated to reflect the construction of new structures and developments over time.

3.2 ORGANISATION AT NATIONAL SCALE

Coastal observatory

Although many Mauritian organisations are active on the coast, there has not always been coordination and cooperation between Mauritian organisations on past actions. The need has been identified for a mechanism to centralise knowledge and data, to adopt a more integrated and open approach. This system could take the form of a coastal observatory integrating all the Mauritian islands. It would include metadata, data, and maps on coastal hazards and risks, and the impacts of climate change on the coast, on hazards, on ecosystems and on the issues at stake. The data is produced by various organisations, universities and companies. Any data, studies, etc. that contribute to the observatory must remain their property. It would be desirable for an organisation to provide data on a voluntary basis, provided that it also had access to data produced by other organisations (give-and-take approach). The organisation owning the data would be responsible for voluntarily completing and updating the data in its possession to guarantee the relevance and quality of the data made available.

This observatory does not necessarily have to be a specific physical entity but could be made up of active representatives from each organisation within the observatory. The observatory would be governed by a Steering Committee, whose role would be to define the main topics of development to be prioritised. It would be assisted by a Scientific Committee covering all topics, which would provide expert support at the request of the members of the observatory. The members of the Scientific Committee could be mobilised to provide expert support at the request of the members of the observatory, but also by local authorities or other public (state, regional, local) or even private structures.

It is necessary to understand the coastal strip in all its dimensions (physical, biological, sociological, economic and others). The studies carried out and the data and results obtained should be an integral part of this observatory. These data should be easily accessible to the various public authorities concerned, as well as to private actors and NGOs active in the coastal zone. These data and documents could be integrated into an Internet portal providing access to various WEB services dedicated to each issue.

Public planning policies for urban and economic development should systematically consider the latest knowledge on coastal hazards and risks. It is necessary to take into account current and future coastal hazard maps to ensure that new developments are not and will not be at risk, or at least to assess the level of risk in full knowledge of the facts. Prudent development that takes account of coastal hazards will enable more sustainable development that is safer for people and property and more resilient to environmental and climatic factors. Investments made will therefore be more sustainable and profitable in the long term.

Risk culture

The sociological study showed that there is a significant gap (especially in Mauritius) between the perception of coastal risks by the different types of stakeholders interviewed and the reality of the hazards, especially in the case of a major event. Indeed, the perceived risks appear to be much more limited in spatial extent and intensity than the reality. Our study shows that future hazards will in most cases be greater than current ones; the gap between perception and future reality is even greater. This gap makes people more vulnerable and less resilient. It therefore seems necessary to develop a risk culture among as many people as possible (whether stakeholders or ordinary citizens). Data and knowledge on coastal risks and hazards and on the effects of climate change should be made accessible to everyone, for example by producing clear educational documents (in various forms: leaflets, videos, etc.) that could be accessed through the Observatory's portal. It could be useful to organise, under the aegis of the local authorities (with the support of the Observatory's experts), popularised scientific information sessions presenting the reality of current coastal hazards, explaining the associated risks, both human and material, and what to do in the event of a major event that could lead to flooding and/or sudden erosion and retreat of the coastline.

Adaptation

The work carried out on the adaptation methods that could potentially be applied in Mauritius shows that there are many of them, and that they fulfil different objectives and offer different services. Some are more long-lasting than others and offer immediate benefits, while others, although reassuring, can entail prohibitive costs in terms of maintenance, adaptation to changing environmental conditions. In addition, some adaptation measures have a negative impact on the hydrosedimentary functioning of the coast and coastal ecosystems and are not part of an approach to reduce greenhouse gas emissions. Finally, they have a lasting impact on the landscape and the attractiveness of the coast as a tourist destination. The choice of adaptation measures must therefore be carefully considered, considering all the factors involved.

The improved hazards knowledge generated by this project means that these hazards can be better anticipated and, that different adaptation solutions can be envisaged, depending on the characteristics of the hazards, but also on the characteristics of the assets concerned, their criticality and strategic importance, their lifespan, etc. The choice of one or more adaptation pathways is therefore inextricably linked to the sector concerned, but also to political choices relating to economic, tourism and environmental development objectives, etc., as well as to social demand. These necessarily political choices would strongly benefit from a national coastal management strategy to address this issue.

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