VULNERABILITY AND ADAPTATION ASSESSMENT TOOLKIT: COASTAL ZONE

User Manual

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Ministry of Social Security, National Solidarity, and Environment and Sustainable Development
(Environment and Sustainable Development Division)
Republic of Mauritius

Vulnerability & Adaptation Assessment (VAA) Toolkit (Mauritius): User Manual for Coastal Zone Sector

About this manual

This VAA-Coastal Zone User Reference Toolkit manual forms part of a family of toolkits to assess vulnerability of climate change for the Coastal Zone Sector. The user reference has been written from an application developer's perspective. A fundamental conceptual and operational knowledge of Excel is assumed.

Disclaimer

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VAA-Coastal Zone Toolkit

1. Introduction

This document refers to a user-friendly toolkit developed to assess vulnerability and adaptation in the coastal zone sector – also known as VAA-Coastal zone Toolkit for the Republic of Mauritius. The VAA for the Coastal Zone was assessed in the Third National Communications (TNC) Report (2016) for the various climate change-related impacts observed in the coastal zone sector in Mauritius.

The VAA-Coastal Zone Toolkit performs basic calculations taking the indicators of the Environmental Vulnerability Index (EVI) under different coastal zone related issues. Applicable coastal zone and related indicators were shortlisted, besides some common indicators about climate. Users of the VAA Coastal Zone Toolkit can adjust the indicators by choosing appropriate parameters/assumptions to suit their needs of the vulnerability assessment.

With the significant warming trend of about 1.2°C, a decreasing trend in rainfall amount of about 8% and a projected rise of sea-level ranging between 52 cm and 98 cm by the end of the century if no mitigating action is taken (IPCC, 2013), the risk from natural disasters arising from extreme events such as cyclones, flood and droughts are expected to increase. Already, according to the World Risk Report 2016, Mauritius is ranked as the 13th country with the highest disaster risk and 7th on the list of countries most exposed to natural hazards (UNU-EHS, 2015). The vulnerability of RoM is projected to increase with these phenomena impacting adversely on its socio-economic and environmental sectors. The assessment of the vulnerability made on the basis of climate trend projections of the regional climate model COSMO-CLM, developed under the Disaster Risk Reduction Strategic Framework and Action Plan 2013 (DRR, 2013), predicts temperature to increase, with a range (depending on the seasons and scenarios) between 1°C and 2˚C for the period 2061-2070, with respect to the period 1996-2005 (TNC, 2016).

The threatening impacts of climate change are increasingly being felt with an accelerated sea level rise, accentuated beach erosion, increase in frequency and intensity of extreme weather events, decreasing rainfall patterns as well as recurrent flash floods. The climate challenges ahead for Mauritius should not be underlooked, especially when considering the facts that water supply by 2030 may not be sufficient to satisfy projected demand, agricultural production may decline by as much as 30% and that several beaches, that are so important for our tourism industry may slowly disappear, thus severely undermining one of our major economic pillars and depriving the economic value of this sector, worth over USD 50 million by 2050.

2. Overview of the Coastal Zone sector

The "**coastal zone**" is defined to include the physical entity of the reefs, lagoons, beaches, and the backshore area. Coastal zones are typified by a complex and dynamic interplay of natural, demographic and economic processes linked to each other in a network of mutual reciprocal influence. These processes are essentially dynamic cycles involving the exploitation of natural resources, the transformation and use of resources for demographic growth, social organization and economic production, and the generation of by-products and their dispersion back into the natural system. Coastal zones are currently experiencing intense and sustained environmental pressures from expanding socio-economic systems and a range of other driving forces (Turner et al., 1996). There is also a growing awareness of these pressures and their linkage to economic development and increasing population growth.

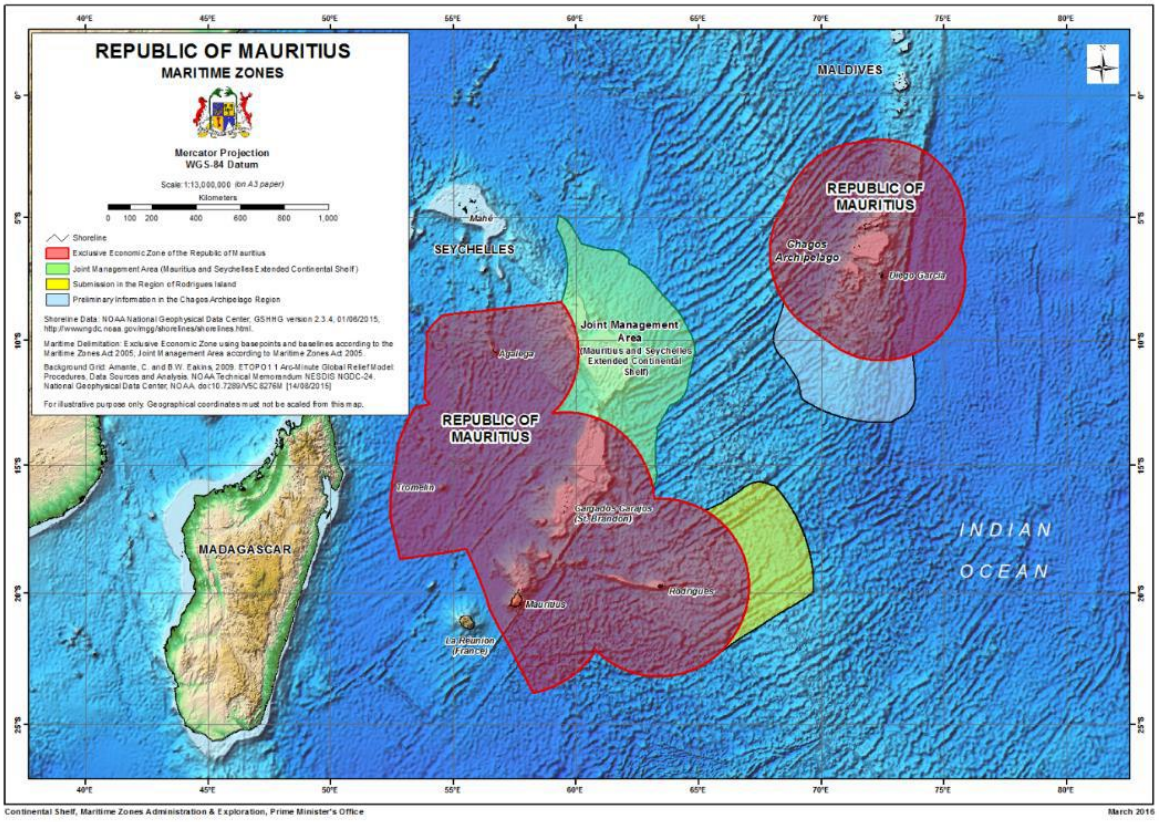


Figure 2.1: Geographical location of Mauritius and Outer Islands

EEZ (light red), Joint Management Area - Mauritius and Seychelles Extended Continental Shelf (light green), Extended Continental Shelf Submission to the UN Commission on the Limit of the continental shelf (CLCS) in the region of Rodrigues (yellow) and Preliminary Information in the Chagos Archipelago Region (light blue).

The coastal zone is one of the natural assets that provides goods and services whose socio-economic development of Mauritius depends. It supports a number of activities including tourism, recreation, fishery, trade, and industry. The total economic value of the coastal resources has been estimated to be about USD 330 M (ICZM Framework, 2010).

Table 2.1: RoM Coastal Zone Statistics (SM, 2009)

(Extended EEZ: Approx 2.3M km2; Land Area: 2040 km2; Population: ~ 1.23M)

	Mauritius	Rodrigues	Agalega	St Brandon	Others#
Max Elevation (m)	828	380	3-4	2	
Land area (km2)	1865	110			
Population					
Coastal population	(~20%)				
Length of coast (km)	322				
Area of lagoons (km2)	243				
Extent of coral reefs (km)	150				
Area of coral reefs	300		28	105	
Number of coastal swamps	44				
Area of mangrove forests (km2)	14				
Type of mangroves	2*				
Islets around Mauritius	49				
Number of public beaches	90				
Length of public beaches (km)	26.6 (8%)				
Number of hotels	104				
Coast length occupied by hotels (km)	41.9				
Marine Protected Areas (ha)	7216				

*(*Rhizopora mucronata* and *Bruguiera gymnorhiza*)

Tromlelin and Chagos Archipelago

The coastal zone of Mauritius has a coastline of mainland Mauritius which stretches some 322 km. The Mauritius coastline encloses an inner land area of some 1865 km^2 and sandwiches some 243 km^2 of lagoon area (and some 49 inner islets) between it and the fringing reef (some 150 km of which surrounds the island). Rodrigues occupies an area of 108 km^2 and is the smallest and probably the oldest of the Mascarene Islands. About 20% of the population resides in coastal areas. The coastline has a varied geomorphology, dominated by sandy beaches and other fragile ecosystems that include marine protected areas and forests coastal mangroves. There are 90 public beaches around the island of Mauritius, with a total length of 26.6 km, making up 8% of the coastline (there are also public beaches on Rodrigues). These attract both domestic and international tourists.

The tourism industry is mainly coastal-based and is the fourth pillar of the economy after the Export Processing Zone, Manufacturing Sector, and Agriculture. The revenue generated directly from activities in the coastal zone was equivalent to 36% of GDP in 2011 – out of which 99% was represented by tourism. This sector is considered to be a highly climate-sensitive economic sector (Ministry of Environment and Sustainable Development, 2012) and the coastal areas are under constant threat and the impacts of climate change are noticeable. These include the increasing frequency of droughts, the growing variability of other extreme climatic events, including severe cyclones and flooding, and rising sea level.

Accentuated beach erosion has shrunk the width of the beaches around certain coastal areas by up to 20m over the last few decades. Significant beach erosion has been observed at Albion, Bel Ombre and Mon Choisy. As a response, various adaptation programmes are being implemented. The minimum setback from high water mark has been increased from 15m to 30m for hotels and residential coastal development. An Integrated Coastal Zone Management Framework has been developed and many coastal activities are controlled through the EIA mechanism. Tourism is envisioned to be a leading and sustainable sector. One of the objectives is to pursue an up-market and selective tourism policy. The emergence of the ocean economy will give a new impetus to cruise tourism with lower CO2 emissions. In order to increase the number of cruise passengers, in the short-term, to 20 000 and, in the medium-term, to 50 000, Mauritius is investing in the construction of a modern cruise terminal by 2016 with a view to improving facilities provided for embarking and disembarking cruise passengers.

Figure 2.2 shows the growing number of international tourists visiting Mauritius from 1983 to 2014. This steady increase does not match its contribution to GDP (Figure 2.3). In 2015, tourist arrivals in Mauritius reached 1,151,723. Tourism sector brought foreign earnings of MUR 50.2 billion, contributed to 7.5% of GDP, and created around 30 000 direct employment. As at end of June 2016, there were 116 licensed hotels of which 111 were in operation and 5 were temporarily closed due to renovation. The total room capacity of these 111 hotels was 13,092 with 27,523 bed places. In order to move the tourism sector to a low carbon growth path, the Ministry of Tourism and External Communications has developed a Mauritian Standard as a management system for sustainable tourism which is to be recognized and accredited by the Global Sustainable Tourism Council.

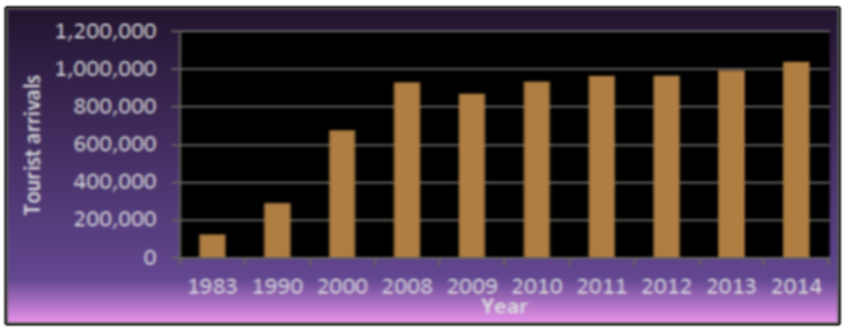


Figure 2.2: Annual tourist arrivals (1983-2014)
Source Statistics Mauritius

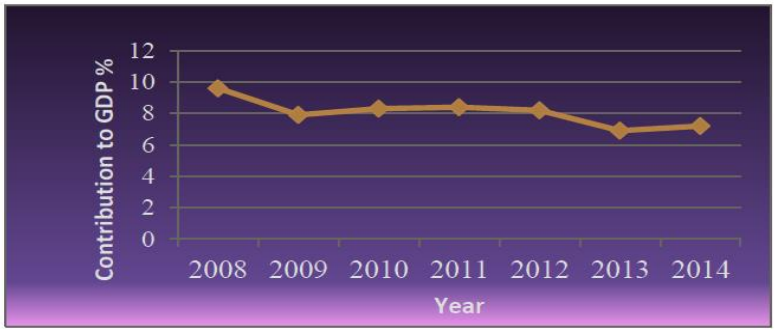


Figure 2.3: Annual contribution of the tourism sector to GDP (%) (2008–2014)
Source: Statistics Mauritius

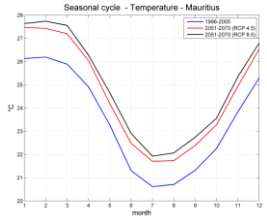
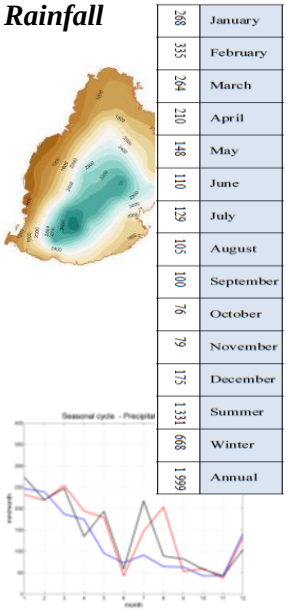
3. Climate, Climate variability and IPCC Forecasts

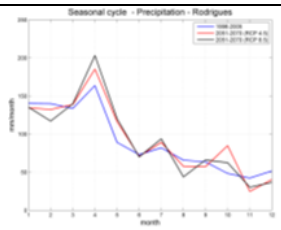
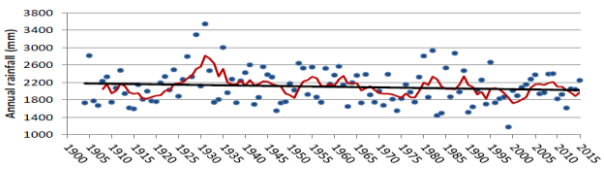
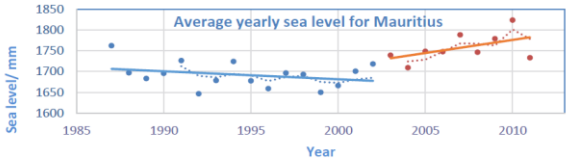
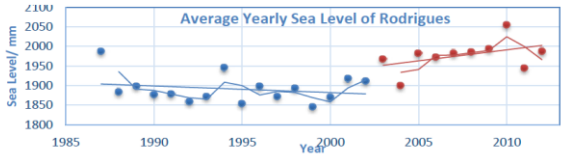
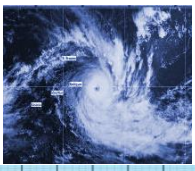
The various islands constituting the Republic of Mauritius (RoM) all enjoy a mild tropical maritime climate throughout the year. With the months of May and October described as transitional months, RoM observes two seasons:

- a warm humid summer extending from November to April and
- a relatively cool dry winter from June to September.

RoM, is located in the tropical cyclone belt of the South Western Indian Ocean (SWIO) where rapid formations of high intensity tropical cyclones and super cyclones have been observed. Table 3.1 shows the trend and projections (including future climate scenario for the region forecasted using IPCC regional models) of key weather parameters (for details see TNC, 2016). Table A1 (Appendix A) contains a list of climate change impact indicators for RoM.

Table 3.1: Trend and Projections of key weather indicators (TNC, 2016)

Indicator (TNC)	*Past and Present Trend (MMS)*	*Projections*
Temperature 	The mean temperature over Mauritius is 24.7°C during summer and 21.0°C during winter. The temperature difference between the two seasons is relatively small and it varies from place to place and is usually larger over coastal areas when compared to the Central Plateau. Records over the period 1951-2014 show a significant warming trend of about 1.2 °C in both Mauritius and Rodrigues. Analysis of temperature records indicate that the observed rate of temperature change is on average 0.020°C/yr and 0.023°C/yr for Mauritius for the period 1951-2014 and for Rodrigues for the period 1961-2014, respectively.	IPCC reckons an increase in mean annual temperature of up to 3.8°C by 2100; Projections made on the basis of RCP 4.5 and RCP 8.5 (the business as usual scenario and the worst case scenario, resp.) indicate an increase in temperature of up to 2 °C over Mauritius and Rodrigues for the period 2051-2070.
Rainfall  288 January 335 February 264 March 210 April 148 May 110 June 129 July 105 August 100 September 76 October 79 November 175 December 1 331 Summer 668 Winter 1 999 Annual	From the mean monthly rainfall data for the period 1981-2010, February is the wettest month and October is the driest. Records over the period 1951-2014 show a decreasing trend in rainfall amount of about 8% for Mauritius and a change in precipitation pattern. For Rodrigues, which is a water scarce island, a downward trend has also been observed in the rainfall compared to the data of the 1960's. The trend and the 5-year moving average for the long-term variations in annual rainfall over Mauritius indicate a steady decreasing trend over the period 1904 to 2015.	A declining trend in total annual rainfall, but an increase in the frequency of intense rainfall episodes (Gastineau and Soden, 2009); Projections for RCP 4.5 and RCP 8.5 scenarios, does not show significant variation with respect to the present rainfall pattern. There will be a shift in rainfall distribution, over Mauritius (e.g., from March to October season). Further reduction in amount of water by 13% by 2050. For Rodrigues, the

	The Central Plateau, the main recharge zone of  the island, has endured a decrease from a maximum of ~4000 m m/year (1951-1980) to ~3800 mm/year with more pronounced drying to the North and the West.	interpretation of the model projections is quite complex as no clear long-term-trend could be identified. However, wide variations emerge across seasons, with a projected decrease in rainfall over the summer months and a likely increase over the transition months.
Sea level	Analysis of sea level data indicates an accelerated rise of 5.6 mm/yr and 5.1 mm/yr for, strikingly, for both Mauritius and Rodrigues, respectively since 2003, much higher than the global average of 3.2 mm/yr. The local mean sea level rose by 2.1 mm/year since mid-90's. The average yearly sea level for the period (1987 to 2011) along with the trend line and the 2-year moving average for Mauritius and those for Rodrigues clearly demarcates into a period when sea level was decreasing (blue) and a period when it is increasing (red).  	Sea level rise (SLR) of 18 – 59 cm by 2100; SLR of about 35 cm if the rate remains constant over the next 90 years;
Cyclones  	Cyclone season is normally from November to mid-May. For the cyclone seasons from 1975-76 to 2014-15, data show that: a) mean number of named tropical storms/cyclones in the SWIO has not changed; b) frequency of storms reaching at least tropical cyclone strength has increased; c) rate of intensification of tropical storms has increased, and a higher number of explosive intensification has been observed over the last 15 years; d) no change in latitudinal cyclogenesis has been observed. For cyclones which reach Category 5 intensity wind gusts can attain over 345 km/h. An increase in the intensity and the rate of intensification is also evident since 1975.	An increase in the intensity and rate of intensification of tropical (Lal et al, 2002);

4. Climate Change: Vulnerabilities, Impacts, and Projections on the Coastal Zone sector

Table A1 (Appendix A) contains a list of climate change impact indicators for RoM.

As a Small Island Developing State, the Republic of Mauritius (including Mauritius, Rodrigues, Agalega, St Brandon and various small islets) is particularly vulnerable to the adverse effects of climate change, especially along the coast - a narrow, sensitive strip upon which the country is so dependent. The visible and measurable effects of climate change in the coastal zone of RoM have become more apparent over the last ten years, reflecting increases in the rate of negative changes in the coastal zone, due to climate change, and an increase in the number of vulnerable sites.

During the last two decades, beach erosion has become important in the North-West, South-West and South of Mauritius where significant losses of space and damage to infrastructure was observed. Agalega and St Brandon who are located just above sea level (maximum of about 2 m) and are partially submerged during cyclones. Remote coral reefs include the Agalega Bank, the Carajados Carajos. This area of importance for coral reefs and the biodiversity they harbor also have biomass important in reef fish, turtles, trophic high-ranking predators and birds.

The major observed impacts of climate change on the CZ and projections for Mauritius & Rodrigues (MMS) are summarized as follows (TNC, 2016):

1. Coral reefs are in a state of deterioration. For Rodrigues, more severe bleaching may lead up to 75% of corals mortality at some sites resulting in a decline in fish population and loss of the protective function of the reef.
2. Accentuated beach erosion has shrunk the width of beaches around certain coastal areas by up to 10 m over the eight years for Mauritius. A loss of sandy beaches of the order of about 5 m every decade for Rodrigues.
3. A projected increase in mean annual temperature extremes coupled with beach erosion can lead to a reduction in tourist arrivals accounting for a revenue loss of up US$ 50 million by 2050.
4. Breeding and reproductivity of various plants and animals species are suspected to have already been affected by the changing climate. It is projected that there will be a greater proliferation of invasive alien species at the expense of native species, a decrease in pollinator activity due to shifts in plant phenology and coastal vegetation, turtle nesting, and wader visitation on low lying islets will be affected (Cheke & Hume 2008; Senapathi 2009; Tatayah 2006, Nicoll et al. 2016; Rane 2005).
5. Sea level rise, causing loss of shoreline, affecting coastal vegetation, turtle nesting, wader visitation on low lying islets and salinization (due to salt intrusion) of low-lying agricultural lands and of the boreholes.
6. Fisheries;

7. Climate stressors leading to other impacts such as:
    a. loss of native forest and stress to animals;
    b. water scarcity (affecting residential, hotels, agriculture, forests, etc);
    c. susceptibility to wild fires;
    d. proliferation of invasive alien species at the expense of native species;
    e. disruptions in the pollination systems/pollinator activity;
    f. soil erosion and soil acidity, affecting vegetation and yields.

The most relevant direct future impacts of climate change upon the CZ include:

i) reduction in tourist arrivals, due to an increase in mean annual temperature along with an increase in temperature extremes (Tourism Council, 2015; GoM, 2012);
ii) accelerated beach erosion due to sea-level rise between 52 and 98 cm by 2100 if no mitigating action is taken (IPCC, 2013).

Figure 4.1 shows all the known coastal sites on the island of Mauritius which are presently vulnerable to the physical effects of climate change (sea level rise, storm surge/flooding, beach erosion). At least 21 beaches are currently experiencing erosion (23% of the beaches on the island of Mauritius), many with accelerated rates in the last ten years. In addition, there are a further 22 sites on the island of Mauritius which have experienced surges and flooding in the recent past (there are additional sites on Rodrigues and Agalega). All sites have value to Mauritians and provide the location for their homes and means for their livelihoods. All need attention, with sound adaptation policies and measures that will make these coastal sites resilient and sustainable during the next period of climate change.

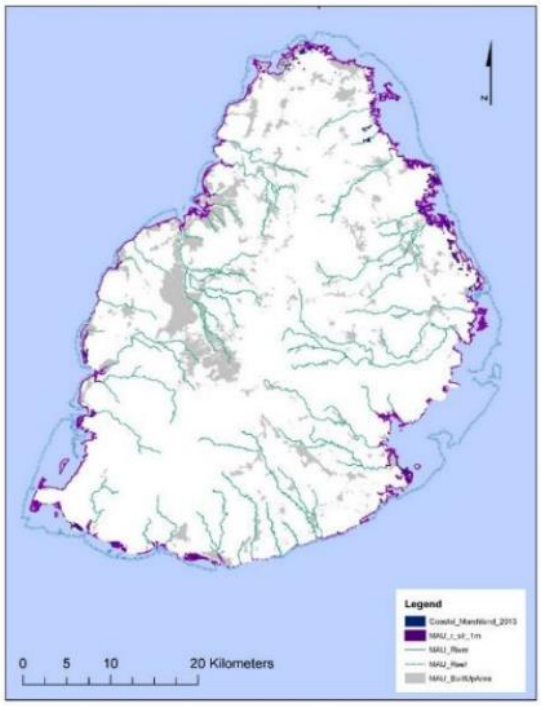


Figure 4.1: Places that are likely to be affected by a sea level rise of 1 m (DRR Report, 2013)

Clearly, most tourists come to enjoy the beaches (34% of tourists are "repeaters"), and the market response in the hotel industry (building hotel capacity in proximity to beaches, although often misinformed as to climate change risks, and causing local problems of beach loss) reflects that. The beaches on the island of Mauritius are near capacity, in terms of visitor use. While new beaches cannot be created, existing ones can certainly be lost. One might argue, then, that the percentage of beach loss, due to climate change, could translate into a similar percentage reduction in the number of tourists, and a correlated loss of revenue and jobs in RoM.

Rodrigues

Several elements of vulnerability to climate change have been observed in Rodrigues. Indeed, we have observed increase in frequency of extreme weather events that have led to floods, soil erosion, landslides and beach erosion.

Port Mathurin may be at risk of being inundated with serious consequences for some 1800 coastal dwellers (GoM, 2015) and the infrastructure. Soil erosion in turn leads to scouring of foundations and collapse of embankments, and landslides cause destruction to buildings and road infrastructure. Figure 4.2 shows a map of Rodrigues indicating the locations most at risk from landslides (map obtained by applying digital terrain models to geological, soil map and land use data) (DRR Report, 2013). This report also show the distribution of agricultural land, built up areas and roads across four levels of exposure to climate-related hazards, namely 1 as low, 2 as medium, 3 as high and 4 as very high, specifically relating to landslides. The main cause of beach erosion in Rodrigues is the continuous sand movement pattern that exists along the beaches, and the presence of hard infrastructure placed on the sea. Sand extraction practices also exist in the Rodrigues lagoon at Banc Catherine. It is estimated that about 25 000 t of sand are removed annually. Though control measures at sand landing station have been strengthened, to this date there is no study that assesses the sand stock required to ensure sustainable exploitation. Furthermore, higher sea surface temperature and sea level rise are foreseen to worsen beach erosion and the problems faced by the fisheries sector in the decades to come.

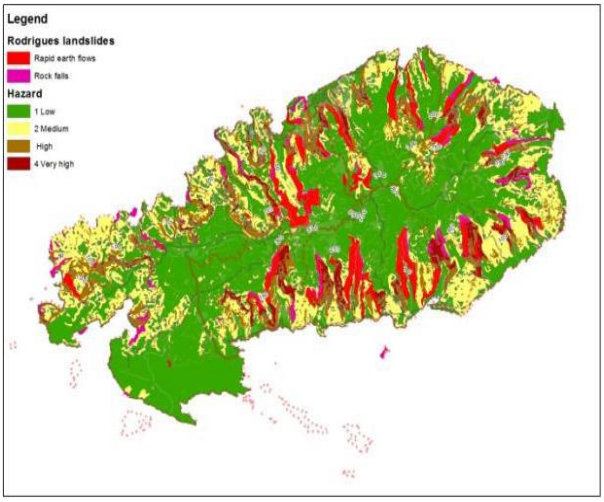


Figure 4.2: Potential landslide hazard map involving rock falls and rapid earth flows (DRR Report, 2013).

Unlike Mauritius, the main economic resource on the coasts of Rodrigues is fisheries combined with some tourism activities. The number of fish and octopus caught during the past few years is on the decline. This decrease is attributed to the loss of marine biodiversity, unsustainable fishing practices, and beach erosion that is causing sedimentation in the sea.

Coral bleaching has been a recurrent problem in Rodrigues. The coral reefs of Rodrigues were some of the few reef areas in the Indian Ocean to escape the mass coral-bleaching event of 1997-1998. The 2016 El-Nino event is believed to have brought massive coral bleaching as per visual inspection made. Unusually warm sea conditions had resulted in coral bleaching, particularly at sites in the North and West of Rodrigues. Surveys showed occurrences of severe bleaching leading to the mortality of up to 75% of corals at some sites. If widespread coral mortality does not decrease in the near future, this may result in a decline in fish population, loss of the protective function of the reef, and a possible increase in toxic dinoflagellates. The

North and West of the island are particularly vulnerable. These areas would benefit from immediate protection in order to allow the corals to recover, and further management measures could be taken to protect the beach from further damage.

Furthermore, some islets such as Ile Coco are vulnerable to sea level rise. Considering a sea level rise at 5 mm/yr, as predicted by a few studies, the loss of sandy beaches may be of the order of 5 m every decade, threatening these islets.

5. Adaptation Strategies proposed under the TNC

Mauritius

In order to address SLR, coral reef decline, and temperature increases, and resulting impacts on coastal erosion, lagoon quality, tourism arrivals and local leisure activities, GoM, in collaboration with other relevant entities, may implement suitable adaptation policies (Table 5.1).

Table 5.1: Adaptation policies aimed at reducing the vulnerabilities of Coastal Zone sector of Mauritius

Action proposed	**Means of implementation and expected results**
Reduce the vulnerability of coastal areas to climate change by considering social, economic and environmental impacts of climate change.	This may be done through: • prevention (e.g. setbacks and relocation) • implementing non-structural (e.g. shore and beach management) • structural interventions (e.g. hard shoreline protection structures like groynes artificial headlands, detached breakwaters and shoreline armouring) aimed at improving environmental as well as economic resilience.
Ensuring coastal protection.	This can be achieved by respecting buffer zones for wetlands and by encouraging coral farming and the growth of coral reefs. *These activities are expected to create synergies, for instance within the tourism sector*
Incentivize resource efficiency for the tourism sector to mitigate costs, while promoting eco-tourism.	With growing expected climate change impacts, operational costs in the tourist sector are expected to increase. Improving resource efficiency may allow the mitigation of cost increases for tourism establishments. An improvement in efficiency, resulting in the use of natural resources, will complement interventions on coastal areas, by valuing native vegetation.
Revive practices utilized in the past.	The practices could include limiting access to beaches (as a form of conservation) to allow for natural restoration, and control developments in the proximity of beaches. A location-based approach could be envisaged.

The implementation of the VAA strategies (Table 5.2) is expected to reduce vulnerability to climate change on coastal areas and, as a consequence, reduce potential economic damage to infrastructure and the operational costs of the tourism sector. This may be achieved while increasing the desirability of Mauritius as a tourist destination, through a more sustainable management of coastal areas including coral reefs and beaches, which would increase the competitiveness of the sector and hence generate employment and income for the local population.

Table 5.2: VAA strategies for addressing current problems and transforming development challenges into new opportunities for achieving the development goals in the coastal area and tourism sector (TNC, 2016)

Sector	Development challenges	Goals	VAA strategies	
			To address current problems	**To create new opportunities**
Coastal areas and tourism	i) Loss of revenues in the tourism sector ii) Vulnerability to climate change coastal erosion, and infrastructure damage	Reduce vulnerability to climate change	**T1[1].** Restoration of coastal vegetation	**TN1[2].** Promoting beach nourishment and dune replenishment
		Ensure coastal protection	**T2.** Coastal wetland protection and restoration	**TN2.** Encouraging coral nursery and growth of coral reefs
		Foster competitiveness in the tourism sector	**T3.** Increase resource efficiency	**TN3.** Incentivise eco-tourism, with the valorisation of natural capital

Note[1]: T1 etc. refer to proposed strategies to address current problems
Note[2]:TN1 etc. refer to strategies for creating new opportunities while addressing the current problems

An integrated approach that identifies the intervention options, which turn challenges into opportunities, the corresponding required investments, and the resulting policy-induced avoided costs and added benefits in the coastal zone sector are given below (Table 5.3).

Coastal areas and Tourism - *Transforming challenges into opportunities* (Mauritius)
Strategies (T1etc.) and corresponding actions (T1.1 etc.) and investments from Households (*H*), Government (*G*) and Private sector (*P*) with resulting policy-induced avoided costs and added benefits

	Strategies	Action List	Investment	Avoided costs	Added benefits
T1	Restoration of coastal vegetation	**T1.1.** Removal of exotic plants that are proven to damage coastal areas. **T1.2.** Planting of native vegetation species	*H:* time, voluntary actions *G:* labour, transport, equipment, herbicides, training *P:* training, co-financing	*H:* property value, injuries *G:* coastal erosion, public spending (coastal infrastructure, health) *P:* property value, insurance	*H:* employment, well-being *G:* carbon sequestration, mitigation of ocean acidification *P:* N/A
T2	Promoting beach nourishment and dune replenishment	**T2.1.** Suitability assessment **T2.2.** Site investigation and source identification **T2.3.**Structural interventions	*H:* N/A *G:* consultancy, contractors (equipment and labour) *P:* training	*H:* leisure opportunities *G:* beach loss *P:* tourism arrivals and revenue	*H:* cultural values and well-being *G:* reduced coastal vulnerability *P:* tourism arrivals and revenue
T3	Coastal wetland protection and restoration	**T3.1.** Re-establishment of salt marshes (vegetative transplant) **T3.2.** Mangroves and seagrass restoration **T3.3.** Improve governance of wetland areas	*H:* equipment and co-financing *G:* survey (site identification), labour, incentives *P:* equipment and infrastructure co-financing	*H:* property value, injuries *G:* coastal erosion, public spending (infrastructure, health) *P:* property value, catch and revenue, insurance	*H:* employment, well-being, leisure (biodiversity) *G:* tax revenue, carbon sequestration, mitigation of ocean acidification *P:* tourism arrivals and revenue
T4	Encouraging lagoon management and coral habitat rehabilitation	**T4.1.** Incentives for coral nursery **T4.2.** Improve regulation for sea-related tourism activities **T4.3.** Encourage sustainable fishing practices	*H:* time, voluntary actions *G:* survey (site identification), consultancy, nursery, propagation, software, labour *P:* training, survey	*H:* property value *G:* coastal erosion, public spending (coastal infrastructure) *P:* property value, catch and revenue, insurance	*H:* well-being, leisure (biodiversity) *G:* tax revenue *P:* tourism arrivals and revenue
T5	Increase resource efficiency	**T5.1.** Incentivise energy and water efficiency as well as water/waste recycle and reuse **T5.2.** Promote certification	*H:* co-financing *G:* incentives, consultancy *P:* training, co-financing, certification fees	*H:* water and energy cost *G:* water stress and water delivery (during droughts), waste landfilling *P:* water and energy cost	*H:* air quality, employment and income *G:* reduced public spending, energy import, emissions *P:* competiveness, resilience
T6	Incentivise eco-tourism, with the valorisation of natural capital	**T6.1.** Branding **T6.2.** Awareness raising **T6.3.** Capacity building	*H:* N/A *G:* consultancy, training package, media strategy *P:* training	*H:* N/A *G:* habitat loss, public spending *P:* attractiveness, competitiveness	*H:* employment and income *G:* tax revenue *P:* tourism arrivals and revenue

Rodrigues

In order to address sea level rise and temperature increase, and the resulting impacts on coastal erosion in Rodrigues, RoM through the Rodrigues Regional Assembly, and in collaboration with other relevant entities, could undertake to:

i) Preserve natural landscapes through the establishment of natural parks for eco-tourism. *This action may not only protect valuable ecological resources and biological diversity but could also foster high-value and low-impact tourism, which ensures more revenues than mass tourism.*

ii) Plant mangroves, build wave breakers at sea and flood wall on the coastline to protect vulnerable on-land infrastructure and build elevated roads or relocate coastal roads more inland. *Mangroves not only act as nurseries for fish and control aspects of water chemistry in coastal zones, they also serve as a critical buffer against storm waves and other extreme weather events*

The implementation of the VAA strategies (Table 5.4) is expected to reduce vulnerability to climate change on coastal areas and, consequently, reduce potential economic damage to infrastructure and the operational costs of the fishery sector.

Table 5.4 VAA strategies for addressing current problems and transforming development challenges into new opportunities for achieving the development goals in the coastal area and tourism sector

Sector	Development challenges	Goals	VAA strategies	
			To address current problems	To create new opportunities
Coastal areas and tourism	i) Preservation of natural landscape ii) Vulnerability to climate change (coastal erosion and infrastructure damage)	Reduce vulnerability to climate change	**T1**[1]. Restoration of coastal vegetation	**TN1**[2]. Promoting the creation of natural parks
		Ensure coastal protection	**T2.** Protection and restoration of ESA	**TN2.** Encouraging coral nursery and growth of coral reefs
		Planning for sustainable tourism	**T3.** Promote best practices (water, energy, etc.)	**TN3.** Incentivise eco-tourism, with the valorisation of natural capital

Note[1]: T1 etc. refer to proposed strategies to address current problems

Note[2]:TN1 etc. refer to strategies for creating new opportunities while addressing the current problems

An integrated approach that identifies the intervention options, which turn challenges into opportunities, the corresponding required investments, and the resulting policy-induced avoided costs and added benefits in the coastal area and tourism sector are given in Table 5.5 below.

Coastal areas and Tourism - *Transforming challenges into opportunities* (Rodrigues)
Strategies (A1etc.) and corresponding actions (A1.1 etc.) and investments from Households (*H*), Government (*G*) and Private sector (*P*) with resulting policy-induced avoided costs and added benefits

	Strategies	Action List	Investment	Avoided costs	Added benefits
T1	Restoration of coastal vegetation	**T1.1.** Removal of exotic plants **T1.2.** Planting of native vegetation species	*H:* N/A *G:* labour, transport, equipment, training *P:* training, co-financing	*H:* property value, injuries *G:* coastal erosion, public spending (coastal infrastructure, health) *P:* property value, insurance	*H:* employment, well-being *G:* carbon sequestration, mitigation of ocean acidification *P:* N/A
T2	Promoting the creation of natural parks	**T2.1.** Site investigation **T2.2.** Establishment of parks **T2.3.**Monitoring for management, compliance	*H:* N/A *G:* consultancy, contractors (equipment and labour) *P:* training	*H:* leisure opportunities *G:* vegetation and biodiversity *P:* landscape fragmentation	*H:* cultural values and well-being *G:* ecosystem integrity *P:* tourism arrivals and revenue
T3	Protection and restoration of ESA	**T3.1.** Mapping of ESAs **T3.2.** Improve governance of ESAs **T3.3.** Mangroves plantation	*H:* N/A *G:* survey (site identification), labour, incentives *P:* equipment and infrastructure co-financing	*H:* property value, injuries *G:* coastal erosion, public spending (infrastructure, health) *P:* property value, catch and revenue, insurance	*H:* employment, well-being, leisure (biodiversity) *G:* tax revenue, carbon sequestration, mitigation of ocean acidification *P:* tourism arrivals and revenue
T4	Encouraging coral nursery and growth of coral reefs	**T4.1.** Incentives for coral nursery **T4.3.** Encourage sustainable fishing practices	*H:* N/A *G:* survey (site identification), consultancy, nursery, propagation, software, labour *P:* training, survey	*H:* property value *G:* coastal erosion, public spending (coastal infrastructure) *P:* property value, catch and revenue, insurance	*H:* well-being, leisure (biodiversity) *G:* tax revenue *P:* fish catch and revenues
T5	Promote best practices (water, energy, etc.)	**T5.1.** Incentivise energy and water efficiency as well as water/waste recycle and reuse **T5.2.** Promote certification	*H:* co-financing *G:* incentives, consultancy *P:* training, co-financing, certification fees	*H:* water and energy cost *G:* water stress and water delivery (during droughts), waste landfilling *P:* water and energy cost	*H:* air quality, employment and income *G:* reduced public spending, energy import, emissions *P:* competiveness, resilience
T6	Incentivise eco-tourism, with the valorisation of natural capital	**T6.1.** Branding **T6.2.** Awareness raising **T6.3.** Capacity building	*H:* N/A *G:* consultancy, training package, media strategy *P:* training	*H:* N/A *G:* habitat loss, public spending *P:* attractiveness, competitiveness	*H:* employment and income *G:* tax revenue *P:* tourism arrivals and revenue

Cross-sectoral considerations

Cross-sectoral considerations (Table 5.6) are now taken into account to identify and highlight entry points for interventions that will lead to increase efficiency of budget allocation and policy implementation. The strategies that more markedly contribute to the overall development include capacity building and awareness-raising, along with improved data collection and analysis. In addition, ecosystem restoration (terrestrial and marine) was identified as an ideal intervention in six of the seven sectors analysed. The main benefits identified when considering cross-sectoral dynamics include a reduction in public spending (with several instances in which avoided costs emerge) along with an increase of public revenues (e.g. tax revenues, through increased economic activity); employment creation (across all sectors and interventions); improved well-being (with better health and a reduction of injuries and diseases); and an amelioration of leisure opportunities (both for the local population and for tourists).

Table 5.6: Policy interventions and their inclusion in sectoral strategies

	Sustainable land use planning	Ecosystem restoration	Resource efficiency	Integrated water management	Climate resilient infrastructure	Eco-tourism	Institutional capacity and support	Awareness raising	R&D and data analysis
Agriculture	√	√		√			√	√	√
Coastal areas and tourism	√	√	√	√	√	√		√	√
Water		√	√	√				√	√
Biodiversity	√	√				√		√	√
Fisheries	√	√					√	√	√
Health					√		√	√	√
Infrastructure		√		√	√	√	√	√	√

Table 5.7 highlights some of the more outstanding opportunities emerging from cross-sectoral linkages for the Coastal Zone sector.

The restoration of wetlands is critical for fisheries and for the protection of infrastructure from storms and sea level rise. The replenishment of dunes prevents the salinization of rivers, and the development of eco-tourism fosters investments in biodiversity conservation. Policies implemented in other sectors can have a positive impact on coastal sector and tourism and may include the integrated management of fisheries. Such an approach may improve the health of coastal ecosystems and enhance investments in resource efficiency (through R&D and infrastructure) and lead to a reduction in ecological footprint of coastal resorts.

Table 5.7: CZ Strategies and opportunities emerging from cross sectoral linkage

Mauritius	Rodrigues
Strategies *• Restore wetlands for fisheries and protection of infrastructure from storms and sea level rise* *• Replenish dunes (to prevent the salinization of rivers, and the development of eco-tourism that fosters investments in biodiversity conservation)* ***Direct Cross cutting issues/ benefits*** *Such steps prevent the salinization of rivers, and development of eco-tourism that fosters investments in biodiversity conservation.* ***Other benefits and remarks*** *Policies implemented in other sectors can have a positive impact on coastal sector and tourism and may include the integrated management of fisheries. Such an approach may improve the health of coastal ecosystems and enhance investments in resource efficiency (through R&D and infrastructure) and lead to a reduction in ecological footprint of coastal resorts*	***Strategies*** *Preserve natural landscapes through the establishment of natural parks for eco-tourism; plant mangroves, build wave breakers at sea and flood wall on the coastline to protect vulnerable on-land infrastructure and build elevated roads or relocate coastal roads more inland.*

6. VAA-Coastal Zone Toolkit

The structure, methodology, and components/modules of the VAA-Coastal Zone Toolkit has been described in the main User Manual.

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8. Appendices

Appendix A

Key Climate Change Impact indicators for RoM

Table A1: Key CC Impact indicators for RoM (source: DRR Report, 2016)

Indicator	*Trend (DRR Report)*	*Cases*
Beach Erosion	17% of the beaches are suffering from long term erosion and that 23% are being accreted, the remaining 59% are considered as being stable. A loss of **10 meters** of beaches over the last 8 years has been observed.	At Pointe aux Cannoniers, in the north of the island the shoreline has retreated by 10m and up to 18m within 45 years from 1967, with the volume of sediment loss amounting to 10,000 m^3. Mon Choisy, the shoreline has retreated by 12m on average and 18m at the maximum within the same period of time with a sediment loss of 20,000m^3 loss. Coral condition at Mon Choisy has been noticed to be relatively worse comparing to other coral reefs in Mauritius.
Flash Floods	Some 19-30 km2 of agricultural land, 5-70 km2 of built up land, 2.4-3 km of motorway, 18-29 km of main roads and 68-109 km of secondary roads are at risk of flooding. The damages to building and infrastructures have been estimated to be around USD 2 Billion in 50 years (2070 horizon).	Increase in the frequency of extreme weather events more frequent torrential rains resulting in flash floods, causing 11 deaths in March 2013. During recent heavy rainfall in January 2015, over 250 sites were flooded in Mauritius. During the first five days of May 2017, Mauritius recorded a mean rainfall of 275mm which represents 186% of the long term mean rainfall for the month; the Eastern part recording almost 300% of its normal rainfall. The flash flood of May 2017 affected around 74 households in the Flacq region namely, Central Flacq and Poste de Flacq (Cite Hibiscus, Camp Poorun and Cite Débarcadére).
Landslides	As heavy precipitation events increase, so does the risk of landslide. In Mauritius, 3 mountainous/hilly zones (enclosing 38 localities) are highly prone to landslide. The estimated values of built up areas and roads exposed to landslide are in the order of 7233 Million USD and 196 Million USD respectively.	These are 3 zones are notably regions around Vallee des Pretres-Chitrakoot, Quatre Soeurs-Louis de Rochecouste and Grande Riviere Noire-Chamouny. Regions such as Chitrakoot and Quatre Soeurs have recurrently been affected by landslide events such that in situ infrastructures are prone to damages. More recently the Terre Rouge-Verdun road was damaged due to landslide after a heavy downpour.
Coastal Inundation and Storm Surges	According to the DRR report, 12.2 km2 of built-up land, 11.8 km2 of expansion areas and 60 km of primary and 80 km of secondary roads are identified at risk to inundation as a result of sea surges. The damages to building and infrastructures has been estimated to be around 1.4 Billion USD for inundation in 50 years (2070 horizon).	According to scenarios established in the DRR, the north area of Mauritius is highly exposed to coastal risk, especially the zone between Pointe aux Cannoniers and Cap Malheureux. Analogously, the entire shoreline between Mon Choisy and Baie de l'Arsenal seem to be subject to significant inundation. Besides, high coastal risk appears in correspondence of Port Louis area from Baie du Tombeau to Baie de la Grande Riviere. The same type of problem is found in the south of Flic en Flac, through Baie de Tamarin up to Baie de la Grande and Petite Riviere Noire. Along the southern border, localized issued are in Pointe aux Roches, Pomponette, Riambel and in Mahebourg. Along the eastern coast, high local risk has been identified at Trou d'Eau Douce, Poste de Flacq and Roche Noires.

Sea water intrusion	Problem of salinity due to sea water intrusion in the water ponds on farms in the south eastern and south coastal belts.	Areas such as Belle Mare, Palmar, Quatre Soeurs and Deux Frères, Bambous Virieux and Pomponette has been observed.
Forest/Bush Fire	Climate change is projected to increase the extent, intensity and frequency of forest fires in certain regions of Mauritius. Warmer summer temperatures, coupled with decreases in water availability, dry out woody/dry grasses materials in forests/grassland increases the risk of wildfire.	Regions that are regularly plagued by wildfires in Mauritius include: Signal Mountain, La Ferme, Ile D'Ambre, Petit Sable and Ile aux Benitiers.
Coral Bleaching	El Niño Southern Oscillation (ENSO) generated massive bleaching and coral mortality during 1982-1983, 1997-1998, 2002-2003, 2005, and 2010, and contributed to the likely extinction of a coral species. In 1998, the NOAA reported an episode of extremely high ocean temperatures migrated from south to north throughout the Indian Ocean during the first six months of 1998 causing considerable coral reef bleaching in its wake. It was estimated that 16% of the world's coral was lost.	Bleaching has been reported in the Indian Ocean reefs of Mauritius as well as in Seychelles, Reunion, Madagascar and Maldives, amongst others. The coral reefs of Rodrigues which escaped the mass coral-bleaching event of 1997-1998, was affected by the 2016 El-Nino event. Surveys showed occurrences of severe bleaching leading to the mortality of up to 75% of corals at some sites, particularly in the North and West of Rodrigues.
Acidification	Since the beginning of the industrial era, oceanic uptake of CO_2 has resulted in acidification of the ocean; the pH of ocean surface water has decreased by 0.1 pH units (high confidence), corresponding to a 26% increase in acidity. The ocean has absorbed about 30% of the emitted anthropogenic CO_2, causing ocean acidification. According to the Fifth Assessment Report of the IPCC, Earth System Models project a global increase in ocean acidification for all RCP scenarios by the end of the 21st century. The decrease in surface ocean pH is in the range of 0.06 to 0.07 (15 to 17% increase in acidity) for RCP 2.6.	