VULNERABILITY & ADAPTATION ASSESSMENTTOOLKIT: BIODIVERSITY

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 Biodiversity Sector

<u>About this manual</u>

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

Disclaimer

Data used has been obtained from reliable sources. The Ministry of Social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division) assumes no responsibility for errors and omissions in the data provided. Users are, however, kindly asked to report any errors or deficiencies in this product to the Ministry. The choices of calculation made in this tool are derived from TNC Report (2016).

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VAA-BIODIVERSITY Toolkit

1. Introduction

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

The VAA-Biodiversity Toolkit performs basic calculations taking the indicators of the Environmental Vulnerability Index (EVI) under different agriculture related issues. Applicable agriculture and related indicators were shortlisted, besides some common indicators about climate. Users of the VAA-Biodiversity 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 Biodiversity sector

Mauritius is designated by IUCN as a "Centre of Plant Diversity" as a biodiversity hotspot in the Indian Ocean. The country is characterized by a high level of endemism, with 39% of plants, 80% of non-marine birds, 80% of reptiles, and 40% of bat species reported as endemic, as a result of the island's location, age, isolation and varied topography. At present, only 2% of the island is under native forest (which is classified as having more than 50% of native plant coverage), with remaining native vegetation confined to marginal lands without agriculture.

Mauritius has a diverse number of species; the native diversity of selected groups in Mauritius is shown in Table 2.1.

Terrestrial Environment

- 691 flowering plant species of which 273 are single island endemics and another 150 are Mascarene endemics (Baider et al., 2010).
- About 9% of endemic plants are extinct and nearly 200 of the surviving plants are red-listed according to the International Union for the Conservation of Nature (Strahm 1993).
- 52 native species of vertebrate, 28 land birds, 17 reptiles, 3 fruit bats, besides insectivorous bats, snails and insects.

Table 2.1: Native diversity of selected groups include the number of extinctions (number in brackets indicate the number of endemic species)

	No. of native species		% species endemic	No. of extinct species		No. of extant species	
Angiosperms	691	(273)	39.5	61	(30)	630	(243)
Mammals	5	(1)	20.0	2	(0)	3	(1)
Land Birds	28	(19)	67.9	16	(12)	12	(7)
Reptiles	17	(16)	94.1	5	(5)	12	(11)
Butterflies	30	(5)	16.7	4	(1)	26	(4)
Snails	125	(81)	64.8	43	(36)	82	(45)

Source: Fifth National Report on Convention on Biodiversity (2015)

The main factors that are responsible for the loss of terrestrial biodiversity include invasive alien species, land conversion and habitat fragmentation, habitat modification for deer ranching and hunting.

Various measures including the restoration of degraded island habitats are being taken to protect critically endangered biodiversity. Other actions taken include the eradication or control of undesired exotic species, investment in required infrastructure for the ex-situ propagation and the cultivation of threatened plants, propagation, replanting and re-seeding of endemic plants, and reintroduction of endemic animals from captive-bred populations.

Marine environment

- some1,700 species (e.g. 786 species of fish, of which about 5% are of commercial value; 17 species of marine mammals; 2 species of marine turtles).

Marine Protected Areas (MPAs) have been established in strategic sites around Mauritius and Rodrigues to protect marine biodiversity. MPAs falls under the Fisheries and Marine Resources Act 2007 as well as the Marine Protected Areas Regulation 2001.

Mauritius maintains 155.2 km^2 of MPAs which amount to 0.01% of its Exclusive Economic Zone. The MPAs encompass six Fishing Reserves and two Marine Parks while those of Rodrigues constitute five Fishing Reserves, four Marine Reserves and the South East Marine Protected Area.

The inventories of two of the Marine Parks in Mauritius revealed the following diversity of the marine biota (TNC, 2016):

- Blue Bay Marine Park: 108 species of coral, 233 species of fish and 201 species of molluscs
- Balaclava Marine Park: 118 species of coral, 289 species of fish and 219 species of molluscs

Management Plans for both of the marine parks were prepared under the United Nations Development Programme (UNDP) and Global Environment Facility (GEF) under project “Partnerships for Marine Protected Areas in Mauritius and Rodrigues” for the 5-year period 2012/13 to 2016/17.

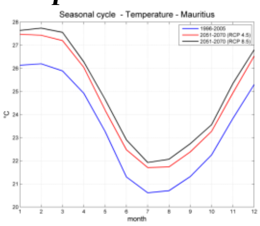
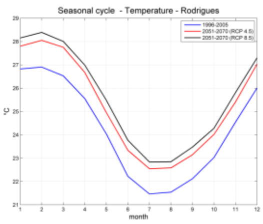
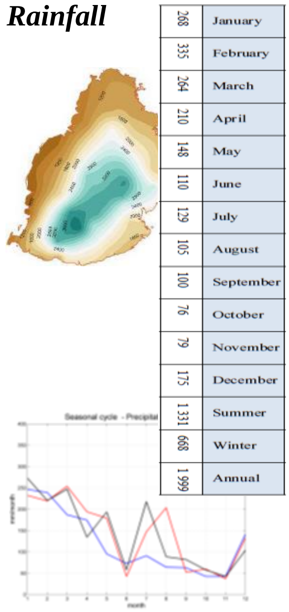
3. Climate, Climate variability and IPCC Forecasts

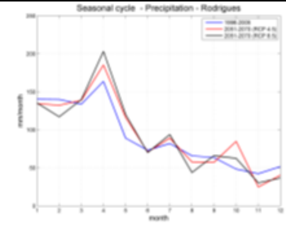
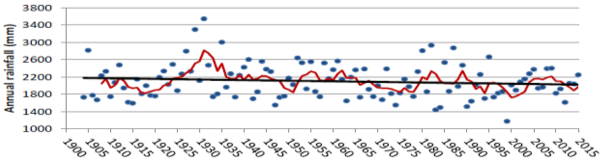
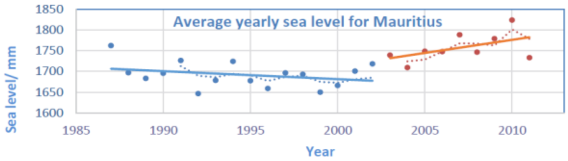
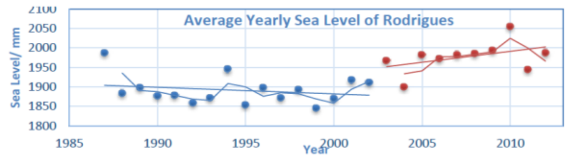
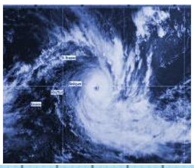
The various islands constituting the Republic of Mauritius (RoM) all enjoy a mild tropical maritime climate throughout the year. With the months of May and October described as transitional months, RoM observes two seasons:

- 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 	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.

	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.	For Rodrigues, the 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 Biodiversity sector

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

Mauritius

Mauritius has one of the most threatened island floras in the world.

Overall, 81.7% of endemic Mauritian flora is now considered threatened and 61 of the country's indigenous species are already classified as extinct (IUCN, 2013). In particular, 141 of the flowering Mascarene endemic plant species are classified as critically endangered (89 taxa are represented by 10 or fewer known individuals in the wild and 5 taxa are represented by only a single known individual); 55 species are endangered and 98 are classified as vulnerable.

As for the fauna, 24 native species of vertebrates that were known to have occurred on Mauritius and the adjacent islets are now extinct, including the Dodo (*Raphus cucullatus*), Broad-billed Parrot (*Lophopsittacus mauritianus*) and two species of the Giant Tortoise (*Cylindrapsis sp*.). Similarly, of the three species of fruit bat (*Pteropus niger, Pteropus niger, Pteropus rodricensis*) known to have occurred, only one – the Mauritian fruit bat (*Pteropus niger*) – remains in Mauritius and is still common locally, however *Pteropus niger* is extinct and *Pteropus rodricensis* occurs only on Rodrigues. Although 12 species of land birds have escaped extinction, 9 of these are threatened. Finally, of the 17 native reptile species known to have once inhabited mainland Mauritius, only 12 remain. Seven of these are restricted to remnant populations on the northern offshore islets and the burrowing boa (*Bolyeria multicarinata*), last seen in 1975, is probably extinct. Six species of reptiles have been successfully translocated from Round Island, Gunner's Quoin and Ile Aux Vacoas to other rat-free offshore islets.A suite of these species is globally, regionally or locally extinct, resulting in an impoverished but yet globally important endemic animal assemblage that includes for example,

- 9 endemic land birds,
- 11 endemic reptiles,
- 1 fruit bat, the insectivorous bats and much fewer insects and snails.

Since the 1970s there have been major efforts to avert extinctions of plants, birds and reptiles, as well as habitat restoration, including forests for sustaining biodiversity, and providing ecosystem services such as carbon sequestration, water regulation, flood control and soil erosion.

In coastal areas, mangrove cover decreased by 30% (20 km^2 to 14 km^2) from 1987 to 1994, and wetlands have either disappeared or are under great pressure due to the expansion of tourism. The marine and coastal environment provides large economic benefits to Mauritian society through activities linked to tourism and fisheries.

The various climate change-related impacts observed in the biodiversity sector in Mauritius are:

(1) change in rainfall pattern on the East coast of Mauritius over a 40 year period, affecting the breeding success and productivity of Mauritius Kestrels Falco punctatus (Senapathi 2009);

(2) possible increasing frequency and intensity in cyclones, affecting hatchability and chick survival of Round Island petrels Pterodroma arminjoniana (Tatayah 2006, Nicoll et al. 2016);

(3) El Nino Southern Oscillation, affecting the proportion of Round Island petrel chicks fledging and recruited into the breeding population (Tatayah 2006, Nicoll et al. 2016);

(4) endemic birds feed on flower buds, flowers, fruits and young leaves of native food plant species (Rane 2005).

Changes in local climate coupled with habitat loss and degraded habitats and the scarcity of natural foods in the Mauritian native forests are strongly suspected to influence the biological cycles of native fauna and flora and to have led to the decline in the endemic birds of Mauritius (Cheke & Hume 2008). Further impacts of climatic change expected, leading to further declines in native fauna and flora.

The most relevant direct impacts of climate exchange expected for the future include:

- temperature rise leading to greater proliferation of invasive alien species at the expense of native species, although some endemic plants may have enough resilience to be able to cope with climate change;
- more severe droughts leading to loss of native forest and increasing stress to animals;
- increasing susceptibility of forests to wild fires causing degradation to ecosystems;
- reduction in pollinator abundance and distribution due to climatic stresses, leading to disrupted pollination systems, hence reduced native plant viability;
- decreased pollinator activity due to shifts in plant phenology;
- high intensity rainfall leading to soil erosion and soil acidity, affecting endemic plants;
- sea level rise, causing loss of shoreline, affecting coastal vegetation, turtle nesting, and wader visitation on low lying islets.

Rodrigues

Rodrigues, most likely the oldest of the Mascarene Islands, houses a very high density of endemic taxa per unit area. Rodrigues has 150 native flowering plants, of which 47 are single island endemics, and 72 are Mascarene endemics (Baider et al., 2010).

A list of endemic species unique to Rodrigues is given in Table 4.1.

Table 4.1: Endemic species unique to Rodrigues (TNC, 2016)

Species endemic to Rodrigues		Nature and status of the species
Species	**Number**	
Bat	2	Endemic to the Mascarenes, of which one is locally extinct
Bird	30	Of these 16 were endemic to Rodrigues or the Mascarenes. Only two endemic Rodrigues species survive
Tortoise	2	All are extinct
Non-chelonian reptiles	7	Six of those were endemic but all six are extinct
Insects and snails	An unsuspected number was known	Most of them are extinct or highly threatened.

Rodrigues has undergone a marked destruction of its native forests (Carl Jones, in Cheke and Hume, 2008) since the island's colonisation in the early 18th century. Forest clearance for agriculture and the advent of forest fires, hunting, mammalian predators and invasive plants has had a heavy toll on the biodiversity of Rodrigues, making it one of the most degraded islands in the world. Of the 36 to 38 taxa of endemic flowering plants, nearly all are threatened (Strahm, 1989). The main threats to forest biodiversity are past forest clearance and unsustainable agricultural practices that lead to habitat fragmentation, soil erosion, and water scarcity. Invasive alien species are rampant both in cultivated and forested areas. However, there are a few and degraded native forest patches which are being restored, namely those. at Grande Montagne, Anse Quitor, and in some of the valleys and on some islets including Ile Cocos and Ile aux Sables.

The most relevant direct impacts of climate change expected in the future are similar to those for Mauritius, and the main ones are given in Table 4.2.

Table 4.2: Projected direct impacts of climate change (TNC, 2016)

Impacts of climate change	Projected impacts on biodiversity and the environment
Temperature rise	Greater proliferation of invasive alien species (e.g. *Lantana camara*) at the expense of native species, although some endemic plants may have enough resilience to be able to cope with climate change
More severe droughts	Loss of native forests and increasing stress to animals
Increasing susceptibility of forests to wild fires	Degradation of ecosystems, especially as invasive species that are fire-prone (e.g. *Heteropogon contortus*) may expand
Reduction in pollinator abundance and distribution due to climatic stresses	Disrupted pollination systems could lead to reduced native plant viability
Decreased pollinator activity	This may be due to shifts in plant phenology
High intensity rainfall	Soil erosion and soil acidity may affect endemic plants
Sea level rise	Loss of shoreline may affect coastal vegetation, turtle nesting, and wader visitation on low lying islets such as Ile Cocos and Ile aux Sables

5. Adaptation Strategies proposed under the TNC (2016)

Mauritius

In order to address the challenges posed by loss of biodiversity and degradation of ecosystems and reduced ecosystems services, and progress towards conserving and increasing biodiversity goals, Mauritius in will suitable adaptation policies (Table 5.1).

Table 5.1: Adaptation policies related to reduction of vulnerabilities of terrestrial biodiversity sector (TNC, 2016)

Action proposed	Means of implementation and expected results
Significantly increase the restoration of native forests, or recreate native forests	Such activities will conserve biodiversity and improve ecosystems services such as regulation of water supply, soil conservation and air quality
Increase ex-situ conservation of plants	Undertaking such actions may serve as a safety measure against extinction, and provide plants for reintroduction into native forests
Increase native animal reintroduction and in-situ management	This activity may reduce risks of decline or extinction of animals and reinstate plant-animal interaction
Expand and improve protected areas	The purpose is to promote the creation of a functional corridor ecosystem
Promote the creation of local capacity	This could be carried out by undertaking research on the effects of climate change on biodiversity, and on the impacts of measures to address these effects
Conduct ecosystems valuation	This objective may be achieved by promoting the importance of biodiversity and mainstreaming of biodiversity

The implementation of these strategies is expected to reduce vulnerability of biodiversity to climate change, improve ecosystems services, support ecotourism and provide forests for the enjoyment of Mauritians (Table 5.2).

Sector	Development challenges	Goals	VAA strategies	
			To address current problems	To create new opportunities
Terrestrial biodiversity	i) Continuous decline in quality of habitats due to invasive alien species ii) Decline in native forest acreage due to development pressure iii) Ecosystems services increasingly compromised iv) Poor policy and enforcement of conservation laws v) Growing impacts of climate change	Exploit synergies (water, soil, leisure, inland tourism, biodiversity protection)	**B1[1].** Catchment areas: eradication of invasive species	**BN1[2].** Reintroduction of native plants in planted forests
		Maintain terrestrial biodiversity	**B2.** Restoration of native forests	**BN2.** Expansion and improvement of protected areas
		Resilience to climate change (e.g. cyclones)	**B3.** Enforce ESAs policies	**BN3.** R&D on impacts of climate change and benefits of native forests

Note[1]: B1 etc. refer to proposed strategies to address current problems
Note[2]:BN1 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 biodiversity sector are given in Table 5.3 below.

Biodiversity - ***Transforming challenges into opportunities*** **(Mauritius)**
Strategies (B1etc.) and corresponding actions (B1.1 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
B1	Catchment areas (mountains and rivers): eradication of invasive species	**B1.1.** Weeding and replanting (proper species) **B1.2.** Maintenance of replanted forest **B1.3.** Relocation of activities	*H:* relocation costs *G:* labour, transport, equipment; herbicides; compensation; training *P:* relocation costs, foregone revenue; training	*H:* water scarcity, food security/expenditure *G:* water distribution, food import, water purification, social tension *P:* water scarcity and cost, fertilizer and pesticides	*H:* fresh water supply, food security, health, employment and income, leisure *G:* water quality and supply, tax revenue *P:* water supply, soil conservation and quality, tourism
B2	Reintroduction of native plants in planted forest	**B2.1.** Propagation of native plants **B2.2.** Gradual clearing and replacement **B2.3.** Maintenance of replanted forest	*H:* N/A *G:* collection of seeds, nursery, labour, equipment, transport *P:* collection of seeds, nursery	*H:* water scarcity, food security/expenditure *G:* ecosystem functions, food and habitat (wildlife), pests and diseases *P:* water scarcity and cost, forgone yield and revenue	*H:* leisure, water, soil and air quality *G:* reduced human/wildlife conflict (e.g. bats), carbon sequestration, resilience *P:* eco-tourism, land value (investment), resilience to cyclone, medicinal plants
B3	Restoration of native forests	**B3.1.** Removal of invasive alien species **B3.2.** Propagation and planting of native plants **B3.3.** Fencing of forest	H: N/A G: collection of seeds, nursery costs, labour, equipment, transport, materials P: collection of seeds, labour, equipment, transport	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* leisure, soil and air quality, aesthetic value *G:* public health and welfare, green jobs, reduced human-bat conflict, respecting conventions and treaties, eco-tourism *P:* eco-tourism, resilience from cyclones, medicinal plants
B4	Expansion and improvement of protected areas	**B4.1.** Identification of suitable zones **B4.2.** Incentives for stewardship **B4.3.** Forest restoration	H: N/A G: survey costs, compensation, land swaps, conservation easement P: collection of seeds, nursery, fencing	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* leisure, soil and air quality, aesthetic value *G:* public health and welfare, green jobs, reduced human-bat conflict, respecting conventions and treaties, tourism *P:* eco-tourism, resilience from cyclones, medicinal plants, land value
B5	Operationalize environment sensitive areas	**B5.1.** Harmonize and update spatial database **B5.2.** Enforcement of ESA categories **B5.3.** Mainstreaming of ESA	*H: N/A* *G:* GIS costs, technical labour, software and data, enforcement costs, review laws *P:N/A*	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* leisure, soil and air quality, aesthetic value, health, flood reduction *G:* public welfare, green jobs, respecting conventions and treaties, eco-tourism *P:* eco-tourism, resilience from cyclones, medicinal plants, land value
B6	R&D on impacts of climate change and benefits of native forests	**B6.1.** Capacity building (institutions and citizens) **B6.2.** Research on climate change and biodiversity **B6.3.** Awareness raising on natural capital	*H:* citizen science *G:* workshops, training, advertising and communication *P:* CSR, use of media, technology development	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* community involvement *G:* public health and welfare, green jobs, land use planning, building resilience *P:* eco-tourism, resilience from cyclones, medicinal plants, land value, patenting

Rodrigues

The policies related to adaption to climate change for Rodrigues are similar to those for Mauritius. As a result, in order to address the challenges posed by loss of biodiversity and degradation of ecosystems and reduced ecosystems services, and progress towards achieving biodiversity goals, RoM through the Rodrigues Regional Assembly, and in collaboration with other relevant entities, including conservation NGOs, could undertake to:

i) Increase significantly the restoration of native forests, or recreate native forests, in order to conserve biodiversity and improve ecosystems services such as regulation of water supply, soil conservation and air quality. This is already a policy decision in Rodrigues, with the Forestry Service creating new forests with native species solely. The Mauritian Wildlife Foundation and the Forestry Service are also restoring large areas of the nature reserves of Rodrigues
ii) Increase ex-situ conservation of plants as a safety measure against extinction, and provide plants for reintroduction into native forests
iii) Address the issue of domestic and stray cattle grazing in forests that accelerate soil erosion and the spread of invasive species
iv) Improve habitats for native animals to use and recolonise forested patches, and reduce risks of decline or extinction of animals, and reinstate plant-animal interaction
v) Expand and improve protected areas to promote the creation of a functional corridor ecosystem, and explore a ridge to reef connection
vi) Promote the creation of local capacity to undertake research on the effects of climate change on biodiversity, and on the impacts of measures taken to address these effects
vii) Conduct ecosystems valuation to promote the importance and mainstreaming of biodiversity

In the biodiversity sector, the development challenges, goals and the VAA strategies to address current problems and create new opportunities are very similar to those of Mauritius. In particular, the implementation of the VAA strategies in Rodrigues is expected to reduce vulnerability of biodiversity to climate change, improve ecosystems services, support eco-tourism, and provide forests for the enjoyment of the population of Rodrigues and visitors.

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 biodiversity sector are given in Table 5.4 below.

Biodiversity - ***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
B1	Catchment areas: eradication of invasive species	**B1.1.** Weeding and replanting **B1.2.** Maintenance of replanted forest **B1.3.** Relocation of activities	*H:* relocation costs *G:* labour, transport, equipment; herbicides; compensation; training *P:* relocation costs, foregone revenue; training	*H:* water scarcity, food security/expenditure *G:* water distribution, food import, water purification, social tension *P:* water scarcity and cost, fertilizer and pesticides	*H:* fresh water supply, food security, health, employment and income, leisure *G:* water quality and supply, tax revenue *P:* water supply, soil conservation and quality, tourism
B2	Reintroduction of native plants in planted forest	**B2.1.** Propagation of native plants and fruit trees **B2.2.** Gradual clearing and replacement **B2.3.** Maintenance of replanted forest	*H:* N/A *G:* collection of seeds, nursery, labour, equipment, transport *P:* collection of seeds, nursery	*H:* water scarcity, food security/expenditure *G:* ecosystem functions, food and habitat (wildlife), pests and diseases *P:* water scarcity and cost, forgone yield and revenue	*H:* leisure, water, soil and air quality *G:* reduced human/wildlife conflict (e.g. bats), carbon sequestration, resilience *P:* eco-tourism, land value (investment), resilience to cyclone, medicinal plants
B3	Restoration of native forests	**B3.1.** Cut and carry strategy **B3.2.** Propagation and planting of native plants **B3.3.** Enforcement of legislation for stray animals	H: N/A G: collection of seeds, nursery costs, labour, equipment, transport, materials P: collection of seeds, labour, equipment, transport	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* leisure, soil and air quality, aesthetic value *G:* public health and welfare, green jobs, reduced human-bat conflict, respecting conventions and treaties, eco-tourism *P:* eco-tourism, resilience from cyclones, medicinal plants
B4	Expansion and improvement of protected areas	**B4.1.** Identification of appropriate area delimitation, fast-track implementation **B4.2.** Incentives for stewardship **B4.3.** Forest restoration	H: N/A G: survey costs, compensation, land swaps, conservation easement P: collection of seeds, nursery, fencing	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* leisure, soil and air quality, aesthetic value *G:* public health and welfare, green jobs, reduced human-bat conflict, respecting conventions and treaties, tourism *P:* eco-tourism, resilience from cyclones, medicinal plants, land value
B5	Operationalize the environment-tally sensitive areas	**B5.1.** Reactivate the Rodrigues Environment Committee **B5.2.** Harmonize env. laws **B5.3.** Amend EPA to form climate change unit	*H: N/A* *G:* GIS costs, technical labour, software and data, enforcement costs, review laws *P:N/A*	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* leisure, soil and air quality, aesthetic value, health, flood reduction *G:* public welfare, green jobs, respecting conventions and treaties, eco-tourism *P:* eco-tourism, resilience from cyclones, medicinal plants, land value
B6	R&D on impacts of climate change and benefits of native forests	**B6.1.** Capacity building (institutions and citizens) **B6.2.** Publication of research, improved access and awareness raising **B6.3.** Research on invasive species and entomology	*H:* citizen science *G:* workshops, training, advertising and communication (Agent de l'Environnement) *P:* CSR, use of media, technology development	*H:* water scarcity *G:* loss of ecosystem functions, food and habitat for wildlife *P:* loss of biodiversity, water scarcity and cost, food and habitat for wildlife	*H:* community involvement *G:* public health and welfare, green jobs, land use planning, building resilience *P:* eco-tourism, resilience from cyclones, medicinal plants, land value, patenting

Cross-sectoral considerations

Cross-sectoral considerations 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 (Table 5.5). The strategies that more markedly contribute to the overall development include capacity building and awareness-raising, along with improved data collection and analysis (TNC, 2016). 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 5.5: Policy interventions and their inclusion in sectoral strategies (TNC, 2016)

	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 5.6 highlights some of the more outstanding opportunities emerging from cross-sectoral linkages for the Biodiversity sector.

The eradication of invasive species in catchment areas has positive impacts on freshwater quantity and quality; the expansion of protected areas is expected to positively affect tourism; and, R&D on the benefits of native species for climate resilience has the potential to support bio-farming and agro-forestry. Policies implemented in other sectors can have a positive impact on the biodiversity sector and may include the reduction of fertilisers and pesticides that negatively impact species diversity, and the adoption of integrated land use planning (with a reduction of land conversion).

Mauritus

Strategies	Direct Cross cutting issues/ benefits	Other benefits and remarks
Eradicate invasive species in catchment areas	Positive impacts on freshwater quantity and quality	Policies implemented in other sectors can have a positive impact on the biodiversity sector include the reduction of fertilizers and pesticides that negatively impact species
Expand protected areas	Positive effect on tourism	diversity, as well as the adoption of integrated land use planning (with a reduction of land conversion).
R&D on impacts of climate change and benefits of native species/ forest	Would support bio-farming and agro forestry	

Rodrigues

Restore/recreate native forests, conserve biodiversity, and improve ecosystems services such as regulation of water supply, soil conservation and air quality and promote the creation of local capacity to undertake research on the effects of climate change on biodiversity, and on ecosystems valuation.

6. VAA-Agriculture Toolkit

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

7. References

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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.	