VULNERABILITY & ADAPTATION ASSESSMENT TOOLKIT: WATER

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 Water

About this manual

This VAA-Water User Reference Toolkit manual forms part of a family of toolkits to assess vulnerability of climate change for the Water 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-Water Toolkit

1. Introduction

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

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

Mauritius received an annual volume of about 4,435 Mm3 of rain water in 2015, out of which 660 Mm3 flows as surface run-off into rivers and groundwater recharge accounts for about 10%, i.e. 445 Mm3 outflow and 1,330 Mm3 is lost through evaporation. In 2013, the total estimated water utilization in Mauritius was 888 Mm3. In 2010, an experimental ecosystem water account was undertaken for assessing the accessible water from river basins to calculate actual water abstraction in order to draw a stress index related to water consumption. Despite some gaps in data availability, this initial assessment of accessible water highlighted irregular conditions with regard to irrigated sugar cane, in particular in the Northern catchment area (Figure 1.11). The Northern Aquifer contributes between 50-60% of domestic water supply in the region thus demonstrating its strategic role in water supply equation to ensure water security. However, the aquifer is susceptible to over exploitation, salt water intrusion and pollution risks all these within the overarching impact of climate change. The IWRM project focuses mainly on the protection of the aquifer against pollution risks including sea water intrusion, through a combination of water resources assessment improving management of the aquifer.

Monitoring climate change parameters has brought to light various trends of importance in assessing future impacts on water resource availability. Of specific interest are trends in temperature increase, which could have a bearing on crop water requirements in irrigated agriculture and change in rainfall amount. The Master Plan for the Development of Water Resources in the Republic of Mauritius (management of resources) provides a road map to realise the integration and management of water resources up to horizons 2025 and 2050. Improving water security and the regularity of potable water supply for the population is a priority of the Government.

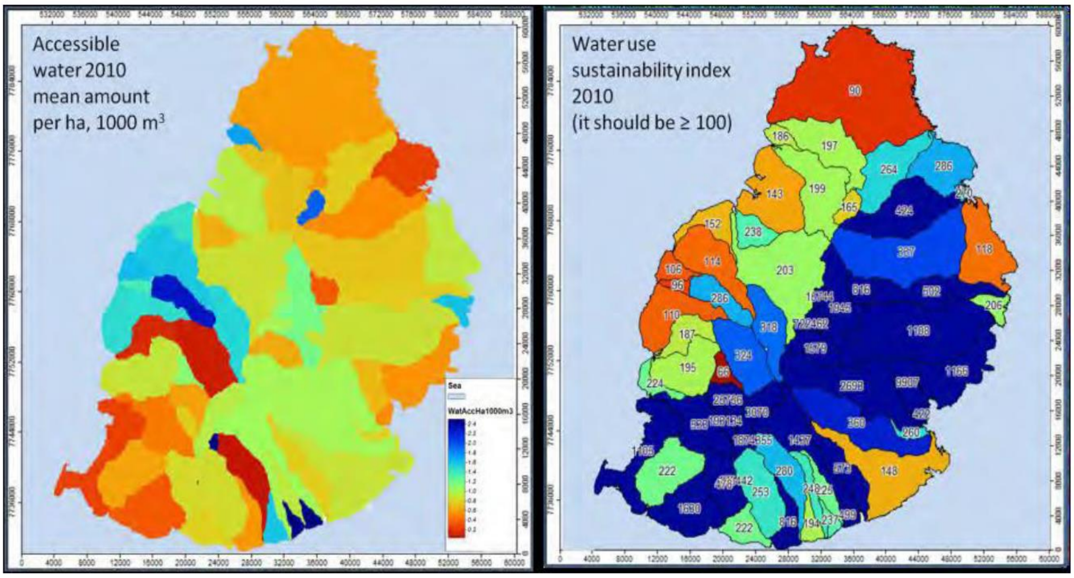


Figure 1.11 Assessment of water accessibility and areas by river basins under risk of stress (Source: Indian Ocean Commission, Experimental Ecosystems Natural Capital Accounts Mauritius case study, June 2014)

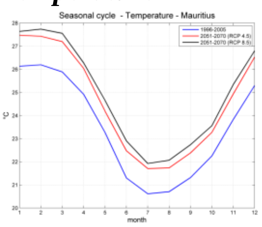
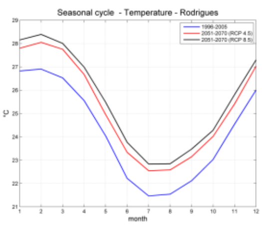
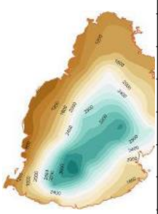
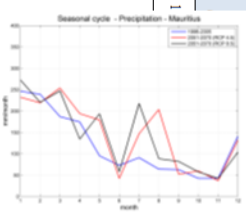
3. Climate, Climate variability and IPCC Forecasts

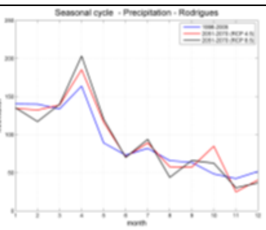
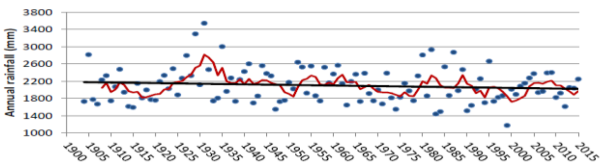
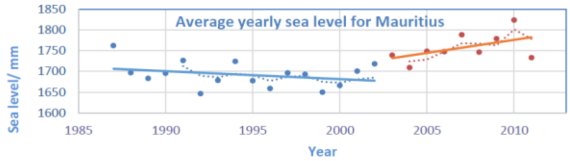
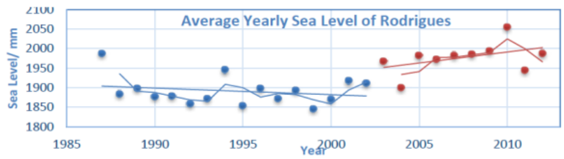
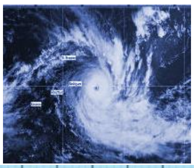
The various islands constituting the Republic of Mauritius (RoM) all enjoy a mild tropical maritime climate throughout the year. With the months of May and October described as transitional months, RoM observes two seasons:

- 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   268 January; 335 February; 264 March; 210 April; 148 May; 110 June; 129 July; 105 August; 100 September; 76 October; 79 November; 175 December 	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

	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.	water by 13% by 2050. 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 Water sector

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

Mauritius

The protection, sustainability, and enhancement of freshwater quality and availability constitute a fundamental prerequisite for long-term socio-economic development. However, the sustainable use of the country's water resources is threatened due to the combined effects of increased demand, climate change impacts such as reduced precipitation and increasing evapotranspiration, contamination and other factors (UNEP, 2014). Already in 2010 water availability was equivalent to 965 m3/person, which is below the threshold for classifying a as water-scarce (GoM, 2012).

The various climate change-related impacts observed in the water sector in Mauritius (GoM, 2012) are:

i) a decreasing trend in annual precipitation of about 8% when comparing 1951-1960 and 1998-2008 figures;
ii) an increase in rainfall variability with heavy rainfall events on the rise; and
iii) the duration of the transitional dry months between winter and summer is becoming longer.

The shift in the onset of summer rain translates into increasing pressure on the water sector to enhance storage capacity in order to cater for longer periods of dry spells and to meet equally growing demands of the agricultural, tourism, industrial and residential sectors the Central Plateau, with the largest catchments in the common recharge zones, has seen a significant decrease in water level which is reflected in changes in ground water and river-flow regimes.

As mentioned above, there has been a decreasing trend in annual precipitation of about 8% compared to the 1950s coupled to an increase in rainfall variability and water scarce periods. Projections indicate that the utilisable water resources may decrease by up to 13% by 2050, if no action is taken to restore catchment areas (Figure 3.1). This trend in the reduction of surface and groundwater recharge may be explained by a reduction in the longer-term trend in precipitation (GoM, 2013). Analysis carried out in the context of the Mauritius Environment Outlook 2011 shows that the total water demand is projected to reach 1,200 million m^3 per year by 2040 based solely on changes in population dynamics. This demand, which does not take into account water demand from other growing sectors of the economy, is in excess of projected supplies and close to the present utilisable renewable potential of 1,233 million m^3 per year (GoM, 2012).

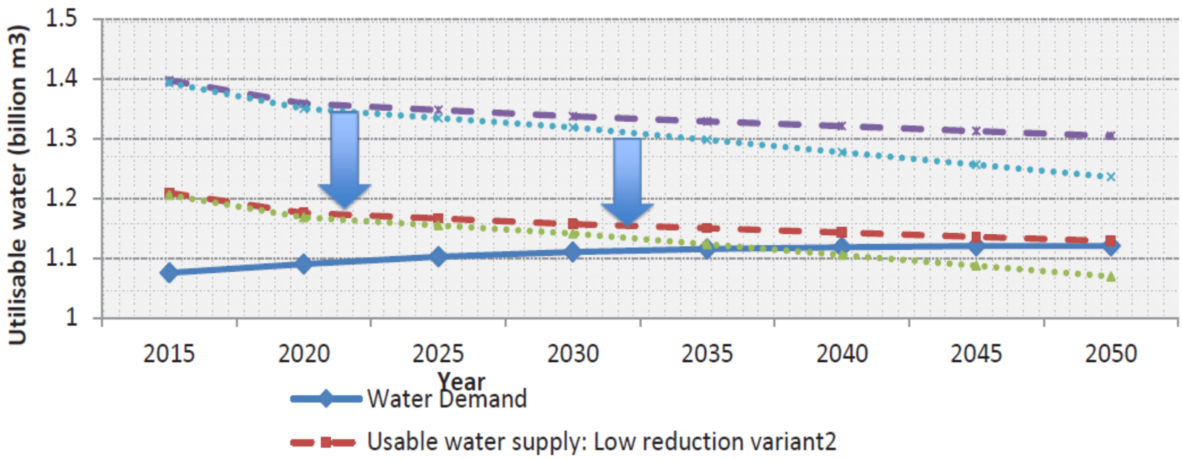


Figure 3.1: Water demand and usable water supply under two different climate change scenarios (source: Government of Mauritius, 2012)

Rodrigues

Rodrigues is a water scarce island.

The main sources of water are rainfall, especially during the heavy rain season, and coastal boreholes. Most of the annual precipitation occurs in the summer months from December to April. Long-term mean annual rainfall is 1,104 mm, with mean rainfall totalling 724 mm (65%) in summer and the remaining 380 mm in winter. Sixteen boreholes provide around 60 to 70% of the water supply in the island.

Traditionally, rain harvesting at household level has been a common practice to address the issue of water shortage. Nowadays, desalination is considered as a valuable option (Figure 3.2) in spite of its high cost. Three plants are now in operation. They supply about 1,250m³ of water per day to the main water network. The establishment of additional desalination plants are being envisaged. However, the high-energy consumption of desalination plants may inevitably lead to an increase in GHG emissions. Moreover, the need to mitigate environmental impacts of the desalination process has to be considered. The process generates a very concentrated and continuous stream of brine. In fact, the management of the plant has to do not only with the generation of potable water, but also with the disposal of the salt extracted.

Figure 3.2 Desalination Plant at Anse aux Anglais. Credit: MoESDDBM

5. Adaptation Strategies proposed under the TNC

Mauritius

In order to address the challenges posed by water scarcity and progress towards reaching national development goals, GoM, in collaboration with other relevant entities, will implement relevant policies (Table 6.1).

Table 6.1: Adaptation policies related to the reduction of vulnerabilities of Water sector (Mauritius)

Action proposed	Means of implementation and expected results
Reduce vulnerability to climate change	The objective may be achieved by fully developing the potential for integrated water resources management in order to maximize preparedness against extreme events (before and after their occurrence), and reduce the impacts of climate change (e.g. salt water intrusion). Interventions may include the development of hydrological models, modernisation of data acquisition and management, and regular maintenance of catchment areas that includes weeding and forest maintenance, thereby improving ecosystem health and reducing soil erosion, as well as improving the combined use of . surface r and ground water
Ensure water availability	The objective may be attained by intervening on both demand and supply. including the rationalisation of water rights. Interventions in the short-term include the introduction of incentives for increasing water efficiency. This could be coupled with activities aimed at enhancing and sustaining ecosystems, increasing usable water supply and ensuring natural filtration. These activities would lead to synergies with biodiversity and tourism sectors
Foster water efficient economic activities	This activity may lead to the growth of new sectors (in addition to improving the efficiency of water use in existing ones) through the monitoring of data to better identify areas where the potential for expansion exists. Location optimisation may be coupled with the expansion of independent water storage capacity to increase the resilience of economic activities

The implementation of VAA strategies (Table 6.2) is expected to reduce water scarcity, by increasing supply and improving efficiency of use. In so doing, the water sector will turn from being a potential constraint to development to an enabler of inclusive growth, through interventions that value natural capital and favour the adoption of new technologies.

Table 6.2: VAA strategies for addressing current problems and transforming development challenges into new opportunities for achieving the development goals in the Water sector (Mauritius)

Sector	Development challenges	Goals	VAA strategies	
			To address current problems	**To create new opportunities**
Water	i) Degradation of ecosystems and water quality ii) Growing demand and constrained supply (water scarcity) iii) Increased vulnerability to climate change	Reduce vulnerability to climate change	**W1.** Fully develop the potential of integrated water resources management	
		Ensure water availability and water quality	**W2[1].** Increase water use efficiency	**WN2[2].** Enhance and sustain ecosystems
		Foster water efficient economic activities	**W3.** Expand water storage	**WN3.** Preserve, upgrade and increase water monitoring and data analysis

Note[1]: W2 etc. refer to proposed strategies to address current problems
Note[2]:WN2 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 water resources sector are given in Table 6.3 below.

Water resources sector - *Transforming challenges into opportunities* (Mauritius)
Strategies (W1etc.) and corresponding actions (W1.1 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
W1	Fully develop the potential of integrated water resources management	**W1.1.** Develop hydrological models **W1.2.** Further enhance forecasting, management, protection and quality of water resources **W1.3.** Modernise data acquisition and management system	*H:* N/A *G:* consultancy, software, training, coordination, data management *P:* data collection and sharing	*H:* water scarcity *G:* water delivery, emergency interventions *P:* water scarcity	*H:* water availability and security, employment *G:* tax revenue *P:* revenues and income
W2	Increase water use efficiency	**W2.1.** Reduce losses in water distribution system **W2.2.** Invest in water infrastructure to support irrigation projects and development of a policy framework to enhance access to, and productive use of, water in the agricultural sector **W2.3.** Promote soil and water conservation techniques (rainwater harvesting, waste water recycling, waste management strategy)	*H:* co-financing *G:* incentives, capital investment in infrastructure, O&M costs *P:* capital and O&M cost, co-financing	*H:* water expenditure *G:* water losses, delivery and cost *P:* loss of productivity and revenue	*H:* water security (supply and access), employment *G:* tax revenue, food security *P:* revenues and income
W3	Enhance and sustain ecosystems	**W3.1.**-Safeguard and protect the ecosystem along water courses **W3.2.** Protect and restore water catchment areas and reduce soil erosion **W3.3.** Awareness campaigns to save water and protect water resources from pollution	*H:* waste disposal for reducing water contamination *G:* labour, transport, equipment; herbicides; compensation; training *P:* training, re-investment in community safety	*H:* water scarcity, food security/expenditure *G:* water delivery, food import, water purification, social tension *P:* water scarcity and cost	*H:* fresh water supply, food security, employment *G:* enhanced ecosystems, water quality and supply, tax revenue *P:* water supply, soil quality, tourism
W4	Expand water storage	**W4.1.** Build new dams and upgrade existing dams to increase water storage capacity **W4.2.** Expand rain water harvesting capacity at household and community level	*H:* co-financing *G:* consultancy, constructor, labour, incentives *P:* co-financing	*H:* water expenditure *G:* water delivery, food import, social tension *P:* loss of productivity and revenue	*H:* water supply, food security, employment *G:* water supply, tax revenue *P:* water supply
W5	Preserve, upgrade and increase monitoring and data analysis	**W5.1.** Incentivise the collection and use of data to understand the mechanisms underlying atmospheric processes that lead to seasonal and geographic distribution of precipitation	*H:* N/A *G:* incentives, labour and training, R&D, data management *P:* training, co-financing, data collections	*H:* water scarcity *G:* malpractice *P:* water scarcity	*H:* employment, human capital *G:* labour productivity *P:* skilled workforce

Rodrigues

In order to address the challenges within the water resources sector and progress towards reaching national development goals, RoM through the Rodrigues Regional Assembly, in collaboration with other relevant entities could undertake to implement suitable strategies (Table 6.4).

Table 6.4: Adaptation policies aimed at reducing the vulnerabilities of the Water sector (Rodrigues)

Increase water use and production efficiency.	Water use efficiency can be increased by improving infrastructures, increasing consumers' awareness, and reducing the need for irrigation in agriculture. On the other hand, water production can be made more sustainable by reducing the environmental impact of desalination
Promote integrated flood management	The process promotes the coordinated management and development of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems
Generate data and improve the reliability of their analysis.	Data processing aids in the understanding of the spatial and temporal patterns in water quality, taking into consideration the natural processes and characteristics of a water body. It allows the impact of human activities to be understood and the consequences of management action to be predicted.

In the water sector, the development challenges, goals and the VAA strategies to address current problems and create new opportunities are very similar to those proposed for Mauritius. In particular, the implementation of the VAA strategies in Rodrigues is expected to reduce water scarcity, by increasing supply and improving efficiency of use. In so doing, the water sector will turn from a potential constraint to an enabler of inclusive growth, through interventions that value natural capital and favour the adoption of new technologies.

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 water resources sector are given in Table 6.5 below.

Water resources - *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
W1	Practice and promote integrated flood management	**W1.1.** Reduce sedimentation, temporarily store floodwaters, recharge aquifers and restore environmental flows	H: N/A G: labour, equipment P: N/A	H: water scarcity, property damage G: water delivery, infrastructure damage, emergency interventions P: property damage	H: water availability, employment and income G: tax revenue P: production and profit
W2	Fully develop the potential of integrated water management	**W2.1.** Complete the Rodrigues Water Act **W2.2.** Improve the coordination of local groundwater storage and with other water supplies	H: N/A G: consultancy, software, training, coordination P: N/A	H: water scarcity G: water delivery, emergency interventions P: N/A	H: water availability, employment G: tax revenue P: revenues and income
W3	Increase water use and production efficiency	**W3.1.** Incentivise the reduction in water use **W3.2.** Support Efficient Water Management Practices in the agriculture sector **W3.3.** Stimulate the recycled and reuse of water	H: co-financing for technology G: incentives P: capital and O&M cost	H: water expenditure G: water delivery P: loss of productivity and revenue	H: water security, employment G: tax revenue P: revenues and income
W4	Enhance and sustain ecosystems	**W4.1.** Protect water catchment areas **W4.2.** Awareness campaigns (e.g. reduced litter and pollution)	H: N/A G: labour, transport, equipment; herbicides; compensation; training P: training	H: water scarcity, food security/expenditure G: water delivery, food import, social tension P: water scarcity and cost	H: fresh water supply, food security, employment G: water quality and supply, tax revenue P: water supply, soil quality, tourism
W5	Expand Water Storage	**W5.1.** Increase surface water storage capacity **W5.2.** Expand rain water harvesting capacity **W5.3.** Incentivise desalination, while taking into account ecosystem protection	H: co-financing G: consultancy, constructor, labour, incentives P: co-financing	H: water expenditure G: water delivery, food import, social tension P: loss of productivity and revenue	H: water supply, food security, employment G: water supply, tax revenue P: water supply
W6	Preserve, upgrade and increase monitoring and data analysis	**W6.1.** Incentivise the collection and use of data **W6.2.** Capacity building (technical empowerment)	H: N/A G: incentives, labour and training, R&D P: training	H: N/A G: malpractice P: N/A	H: employment, human capital G: labour productivity P: skilled workforce

Cross-sectoral considerations

Cross-sectoral considerations (Table 6.6) 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 6.6: 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 6.7 highlights some of the more outstanding opportunities emerging from cross-sectoral linkages for the Water Resources sector.

The protection and restoration of water catchment areas can have positive impacts both on agriculture because of a reduction in costs associated with water pumping, and on biodiversity because of the value that freshwater ecosystems have on biodiversity conservation. Reducing sedimentation may decrease the costs associated with infrastructure maintenance and coastal erosion which, in turn, negatively impact coastal areas and tourism. Activities aimed at increasing awareness on water consumption can lead to a reduction in costs for households and the tourism sector. On the other hand, desalination has to be carefully assessed due to the potential consequences on coastal areas and lagoons. Further, policies implemented in other sectors can have a positive impact on the water sector. For example, the adoption of smart agriculture practices can reduce the amount of water needed for irrigation and reduce chemical contamination of underground aquifers by leaching.

Table 6.7: Strategies and opportunities emerging from cross sectoral linkage for the Water sector

Mauritius	Rodrigues
Strategies 1 • Protect and restore water catchment areas. • Increase awareness on water consumption ***Direct Cross cutting issues/ benefits*** • Can lead to a reduction in costs for households and the tourism sector.	***Strategies*** Increase water use and production efficiency; promote integrated flood management, rehabilitate and improve the distribution system of potable water, the construct desalination plants powered by wind energy, and identify potential small dam sites to cater for medium and long-term water needs of the population.
Strategies 2 • Reduce soil erosion ***Direct Cross cutting issues/ benefits*** • Reduction in costs associated with water pumping– and on biodiversity –because of the value that freshwater ecosystems have on biodiversity conservation. • Reduction in the costs associated with infrastructure maintenance and coastal erosion as it impact negatively on coastal areas and tourism	
Other benefits and remarks Policies implemented in other sectors can have a positive impact on the water sector, such as the adoption of smart agriculture practices that can reduce the amount of water needed for irrigation and reduce chemical contamination of underground aquifers by leaching.	

6. VAA-Water Toolkit

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

7. References

- Gastineau and Soden (2009). G. Gastineau, and B. J. Soden, 2009. Model projected changes of extreme wind events in response to global warming, Geophys. Res. Lett. 36, L10810, doi:10.1029/2009GL037500
- ICZM (201X). Ministry of Environment and Sustainable Development; ICZM Division observations.
- Internet_01. https://www.adaptation-fund.org/wp-content/uploads/2015/01/ilovepdf.com-9.pdf
- IPCC (2006). Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
- Lal et al. (2002). Lal, M., Harasawa, H., Takahashi, K. 2002. Future climate change and its impacts over Small Island Developing States. Climate Research 19: 179 – 192
- MMS (2008a). Mauritius Meteorological Services (MMS): Climate change impacts on Mauritius. 2008.
- MMS (2008b). Technical Report CS28. Cyclone Season of the Southwest Indian Ocean, 2006-2007.
- MAIFS (2016). Strategic Plan 2016 – 2020. Ministry of Agro-Industry and Food Security.
- TNC (2016). Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Mauritius, Port Louis
- UoM (2010) University of Mauritius: Inception Workshop discussions, September 13, 2010.
- Adame, M. et al., 2015. Carbon stocks and soil sequestration rates of tropical riverine wetlands. *Biogeosciences*, Volume 12, pp. 3805-3818.
- Ajonina, G. et al., 2014. *Carbon pools and multiple benefits of mangroves in Central Africa: Assessment for RED+*, s.l.: s.n.
- ASCLME, 2012. *National Marine Ecosystem Diagnostic Analysis. Mauritius. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (UNDP & GEP funded)*, New York: UNDP.
- Association pour le Développement Durable, 2015. *Preliminary results of survey among women on awareness about climate change. Paper presented at the Climate Change Colloquium "Engaging stakeholders on Climate Change issues for the Paris Climate Change*, Curepipe: ADD.
- Baguant, J. A. U. B. B., Beeharry, R. & Nabheebucus, R., 1996. *Part 1 – Mauritius, in Transport Energy in Africa (Ed. M.R. Bhagavan).* London, Zed Books.
- Deenapanray, P. N. & Bassi, A. M., 2015. System Dynamics Modelling of the Power Sector in Mauritius.
- *Environmental and Climate Technologies*, 16(1), pp. 20-35.. DRR, 2013. *Development of a DRR Strategic Framework and Action Plan*, Port Louis: Government of Mauritius. FAO, 2013. *Bioenergy and Food Security Country Brief of*

Mauritius, Rome: FAO.

- Focks, D. A., 1995. A simulation model of epidemiology of urban dengue fever: literature analysis, model development, preliminary validation, and samples of simulation results. *American Journal of Tropical Medicine and Hygiene,* 53(5), pp. 489-506.
- GoM, 2012. *Development of a DRR Strategic Framework and Action Plan,* Port Louis: Governmentt of Mauritius. GoM, 2012. *Technology Needs Assessment,* Port Louis: Government of Mauritius. GoM, 2012. *National Climate Change Adaptation Framework,* Port Louis: Government of Mauritius. GoM, 2012. *Technology Needs Assessment,* Port Louis: Government of Mauritius.
- GoM, 2015. *Intended National Determined Contributions,* Port Louis: Government of Mauritius. GoM, 2016. *Strategic Plan 2016-2020 for the Food Crop, Livestock and Forestry ,* Port Louis: Government of Mauritius. IPCC, 2006. *2006*
- *IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use.* , Geneva: IPCC.
- IPCC, 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* Geneva: IPCC.
- Senapathi, D. et al., 2009. Evidence for long-term regional changes in precipitation on the East Coast Mountains in Mauritius. *International Journal of Climatology ,* Volume 30, p. 1164.
- UNEP, 2014. *Green Economy Assessment for Mauritius,* Nairobi: UNEP.
- UNFCCC, 2016. *Standardized Baseline Grid Emission Factor of Mauritius: Clean Development Mechanism Executive Board,* Bonn: UNFCCC.
- WRI & UNDP, 2015. *Designing and Preparing Intended Nationally Determined Contributions (INDC),* New York: UNDP.

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.	