# VULNERABILITY & ADAPTATION ASSESSMENT TOOLKIT: AGRICULTURE

## 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 Agriculture Sector

## About this manual

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

# VAA-Agriculture 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-Agriculture Toolkit for the Republic of Mauritius. The VAA for the agriculture was assessed in the Third National Communications (TNC) Report (2016) for the various climate change-related impacts observed in the agriculture sector in Mauritius.

The VAA-Agriculture 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-Agriculture 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 Agriculture Sector

The agricultural sector continues to play a vital, multi-functional role within the economy in absolute terms, and has significant economic, social and environmental impacts. Agriculture occupied 42% of the land area in 2005 and is dominated by sugar cane cultivation whose contribution to the GDP represented only 3.2%. In 2016, Mauritius contributed about 0.01% to the global GHG emissions, of which 2.4% comes from the Agriculture sector.

**Sugar sector**

The past decade has witnessed significant transformation of the sugar industry into a cluster maximising on the use of its by-products including bio-energy. This transformation was triggered by a decline of 36% of sugar prices following the European Union (EU) Sugar Regime reform which reviewed the guaranteed preferential access to the EU as well as the guaranteed minimum price. Sugarcane cultivation is undertaken by large commercial estates and nearly 15,600 small farms (MSIRI, 2016). From 2004 to 2014, the area under sugarcane has fallen by 27% to 50 694 ha in 2014 (MSS, 2015). Correspondingly, sugar production in dropped from some 572 000t to around 400,000 t in 2004.

Future strategies aim at contributing to the long-term sustainability of a resilient Mauritian sugarcane industry while capitalising on the multi-faceted potential of the sugarcane plant to deliver a multitude of components, either naturally or industrially with limited impact on the environment. In this regard, a measure that may contribute is fair trade certification for small and medium sugarcane planters. With increasing emphasis on the use of clean and renewable energy, bagasse and cane trash, by-products of the milling process, is gaining importance. Currently, co-generation of electricity using bagasse proper is 340 GWh (LMC, 2015), representing 15% of national electricity demand.

**Non-Sugar sector**

77% of the food requirements of Mauritius are imported; the main items imported include wheat, rice, oil, fresh fruits, meat and milk. Over time, the amount imported continues to go up, indicating an increasing dependency on imported food. Food-crop production annually aggregates to 110,000 t with some 8,200 ha of land devoted it. Agricultural production is undertaken by a relatively large number of small producers and the corporate sector. Some 8,000 small farmers cultivate a range of food crops and a small number of farmers grow fruits and flowers for the export markets. Livestock production is carried out by some 5,000 farmers engaged mainly in cattle, goat, sheep, pig, deer, poultry, and rabbit farming. Local production in 2014 met only 9% of the country’s requirements for meat (excluding poultry) and 4% for milk, whilst 100% self-sufficiency was achieved for poultry meat, eggs and venison. A Strategic Plan 2016-2020 for the Food Crop, Livestock and Forestry has been approved with the overall goal of raising the national food security level in a sustainable manner. The Plan, which is being implemented, focuses on promoting the sustainable management of land, water and other natural resources, and on building capacity to enable farmers to face climate change and move on to ‘climate-smart agriculture’ and (good agriculture practices including bio-farming (promotion scheme).

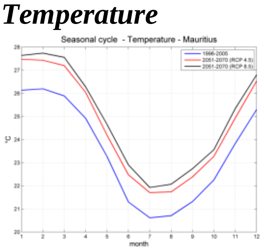
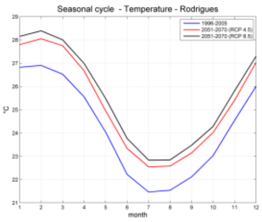
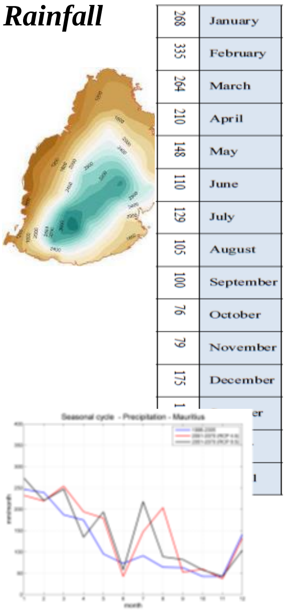
# 3. Climate, Climate variability and IPCC Forecasts

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***<br><br><br><br> | The mean temperature over Mauritius is 24.7°C during summer and 21.0°C during winter.<br>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;<br><br>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***<br><br> | From the mean monthly rainfall data for the period 1981-2010, February is the wettest month and October is the driest.<br><br>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.<br><br>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);<br><br>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 |

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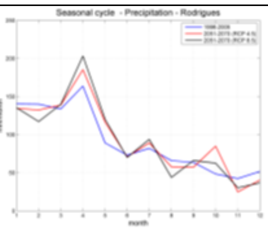
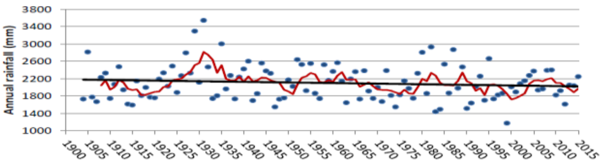
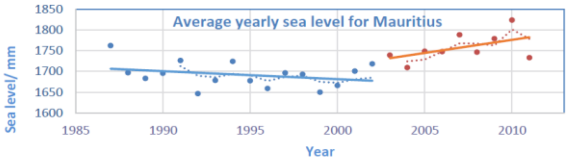
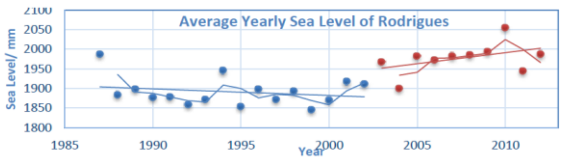
<td><br></td>
<td>The Central Plateau, the main recharge zone of<br><br><br>the island, has endured a decrease from a maximum of ~4000 m m/year (1951-1980) to ~3800 mm/year with more pronounced drying to the North and the West.</td>
<td>water by 13% by 2050. For Rodrigues, the interpretation of the model 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.</td>
</tr>
<tr>
<td>Sea level</td>
<td>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.<br>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).<br><br><br><br></td>
<td>Sea level rise (SLR) of 18 – 59 cm by 2100;<br><br>SLR of about 35 cm if the rate remains constant over the next 90 years;</td>
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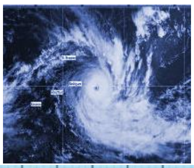
<td>Cyclones<br><br></td>
<td>Cyclone season is normally from November to mid-May. For the cyclone seasons from 1975-76 to 2014-15, data show that:<br>a) mean number of named tropical storms/cyclones in the SWIO has not changed;<br>b) frequency of storms reaching at least tropical cyclone strength has increased;<br>c) rate of intensification of tropical storms has increased, and a higher number of explosive intensification has been observed over the last 15 years;<br>d) no change in latitudinal cyclogenesis has been observed.<br>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.</td>
<td>An increase in the intensity and rate of intensification of tropical (Lal et al, 2002);</td>
</tr>
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# 4. Climate Change: Vulnerabilities, Impacts, and Projections on the Agriculture sector

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

**Mauritius**

Mauritius, with ~ 48.3% of its total land surface area under agriculture, uses ~68% of the total water withdrawn (FAO, 2013). RoM is striving to improve food security but the expansion of the agricultural sector is constrained by increased climate variability and loss of key ecosystem services (see Table 4.1) (UNEP, 2014). The vulnerability of the agriculture sector is expected to increase in the coming decades.

Current trends show that a reduced rainfall and an increase in evapotranspiration due to warming may lead to a decline in agricultural production by as much as 15-25% in the medium- and longer term (Figure 4.1) (Ministry of Environment and Sustainable Development, 2012). With a decrease in rainfall of 10 to 20% and an increase in temperature of 2 $^{o}$C, reductions in cane yield is expected to range from 34 to 48% while reductions in sugar yield is expected to range from 47 – 65% (Table 4.1). Higher temperatures and lower temperature amplitude will lead to increased vulnerability of vegetables and other crops (e.g. due to a change in phenology and reduced flowering intensity), with reduction in yield and productivity (GoM, 2012). This is the case with tomatoes. The monthly yield, which is estimated as a weighted average for several crops in the Eastern region, may possibly decline by 8.2% in the short-run and 13.3% in the long-run with a 1°C temperature increase and 10% precipitation decrease (GoM, 2012). Increase mortality in poultry and incidence of pests and crop diseases leading to a decrease in crop productivity, due to heat stress have been observed. Saltwater intrusion has also been affecting agricultural farms situated in certain low lying coastal zones.

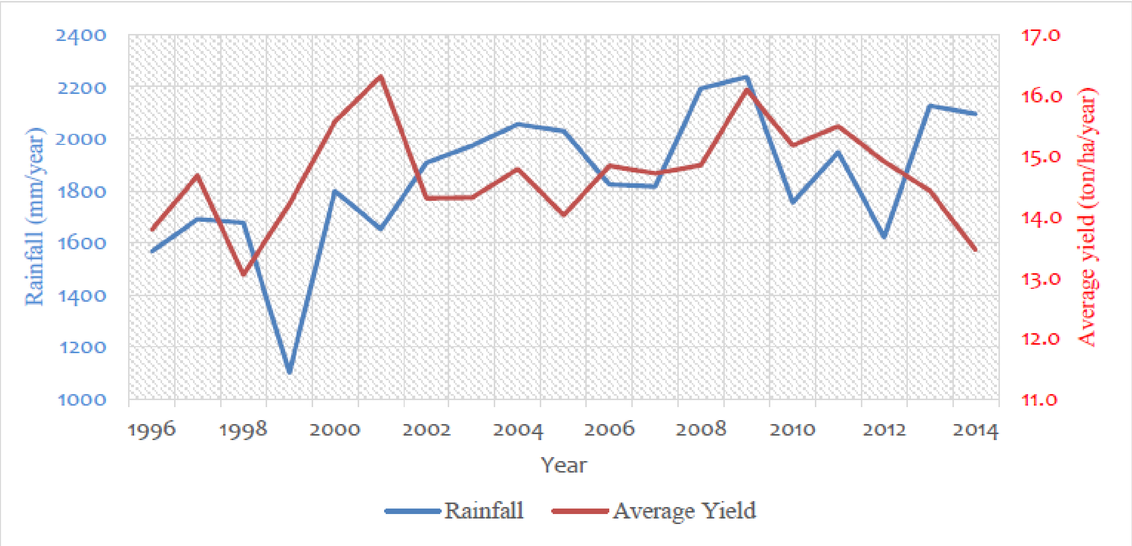


**Figure 4.1: Annual rainfall (in blue) and average annual agricultural yield (in red) (1996-2014) (Source: Statistics Mauritius)**

**Table 4.1 Climate change-related impacts on agriculture (TNC, 2016)**

| Climate variability and climate change impacts | Observed impacts on agriculture |
|---|---|
| **Temperature rise of 0.74 to 1.1°C in the period 1998-2008 relative to 1951-1960** | Affects soil moisture and leads to a shift in agricultural zones; and causes heat stress, which lowers crop productivity and increases mortality in poultry and incidence of agricultural pests and crop diseases. (Ministry of Environment and Sustainable Development, 2012) |
| **Increase in rainfall variability and drought periods, with an 8% decline in rainfall in the last 60 years, comparing 1998-2008 to1951-1960** | Leads to soil erosion, with higher risks of flooding and crop damage, and an overall decline in yields |
| **Increase in climate extremes** | Damages crops and farm buildings, causing loss of animals, and increase in the leaching of plant nutrients and fertilizers to groundwater (GoM, 2012) |
| **Sea level rise** | Leads to the salinisation of water used for irrigation in coastal zones, and causes coastal flooding and loss of agricultural land around the coast |

**Rodrigues**

The mainstay of the economy in Rodrigues, not only in terms of income generation, but also in terms of employment, is Agriculture. Whilst traditional farming systems produce the basic food commodities, adverse climatic conditions and water stress, however, have severely constrained agricultural development (Table 4.2).

**Table 4.2: Climatic conditions that constrain agricultural development (TNC, 2016)**

| Observed change in climatic conditions | Consequences |
|---|---|
| Rainy season has become shorter | Rainfall patterns are becoming more erratic |
| Tropical cyclones are becoming less frequent | There is less available water. Cyclones contribute to more than 60% of annual rainfall |
| Acute shortage of water for irrigation, and the trend is worsening | Several incidences of crop damage from irrigation using coastal boreholes have been recorded, due to salt-water intrusion |
| Rainfall is now drastically low | There is the need to revisit known adaptive measures |
| Both summer and winter rainfall patterns have changed, with the onset of the rainy season occurring earlier than in the past | Hence farmers find it more appropriate and profitable to start planting rain-fed beans and onions in February/March instead of April/May as they used to. The flowering of fruit trees is also occurring earlier than in the past |

Rodrigues experiences major soil erosion problems with soil fertility considerably reduced over time. Fodder is available only on high ground and has almost disappeared in the coastal regions. Livestock has also suffered from changes in climate patterns.  Increase mortality in poultry and incidence of pests and crop diseases leading to a decrease in crop productivity, due to heat stress have been observed. Like in Mauritius, saltwater intrusion has also been affecting agricultural farms situated in certain low lying coastal zones with many incidences of crops damage from irrigation observed. Flowering of fruit trees is occurring earlier and shifting of planting rain-fed beans and onions in February/March instead of April/May.

# 5. Adaptation Strategies proposed under the TNC (2016)

**Mauritius**

In order to address the challenges posed by climate change impacts, make progress towards achieving competitiveness in the agricultural sector and meet national targets in food security, GoM, in collaboration with other relevant entities, will actively support the transition to sustainable agriculture (Table 5.1).

**Table 5.1: Adaptation policies related to the reduction of vulnerabilities of Agriculture sector (TNC, 2016)**

| Strategy | Means of implementation and expected results |
|---|---|
| Improve resource efficiency, specifically in relation to the use of land, fertilizers and pesticides | The aim is to reduce vulnerability to climate change by increasing land productivity with sustainable practices. This will also lead to reduced volatility in production, and ensure stable revenues and access to domestic and foreign markets for sustainable (e.g. Fair Trade) and organic products |
| Estimate the economic value of natural capital | This may be achieved by increasing the knowledge and use of sustainable land use practices and promoting the use of ecosystem services, and in this way address ecological scarcity and reduce the loss of ecosystem services that are costly to replace |
| Support the strengthening of the capacity of institutions | The institutions need to train their human resources as well as those of the local communities. This will ensure the prompt and proper uptake and use of technologies and agriculture practices, leveraging both public and private investments. It will also ensure increased resilience of the agriculture sector in the provision of food (e.g. strategic crops), and in lowering the burden of imports |
| Stimulate research and technology development | The objective may be attained by the identification, development and breeding of crop varieties capable of adapting to climate change and bringing technologies to farmers to increase their resilience to climate change. To this end, effective communication for the transfer and dissemination of information on climate change could be arranged |

The implementation of VAA strategies (Table 5.2) is expected to reduce vulnerability to climate change, increase yields, maintain employment, and reduce both the loss of natural capital (e.g. through decrease in soil erosion) and the carbon footprint of the sector by reducing sources and increasing sinks.

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

| Sector | Development challenges | Goals | VAA strategies | |
|---|---|---|---|---|
| | | | **To address current problems** | **To create new opportunities** |
| Agriculture | i) Food insecurity<br>ii) Vulnerability to climate change<br>(iii) Increased dependence on food imports<br>(iv)Resurgence of livestock and poultry disease | Reduce vulnerability to climate change | **A1[1].** Water supply and conservation support | **AN1[2].** Preventing, preparing for, and responding to agricultural invaders, pests and diseases |
| | | Enhance food security | **A2.** Sustainable land use planning practices | **AN2.** Promote working landscapes with ecosystem services to improve agro-biodiversity |
| | | Foster sustainable agricultural development | **A3.** Building and sustaining institutional support | **AN3.** Research, innovation and technology development and communication |
| | | Reduce vulnerability of livestock and poultry farms to incidence of pest and diseases | Reinforcing capacity building and logistic facilities of Veterinary services for disease surveillance | Looking forward for a contingency plan for livestock sector: Preventing, preparing for, and responding promptly to pests and diseases in order to reduce economic losses |
| | | | Sensitizing farmers on importance of adopting biosecurity measures on farm | |

Note[1]: A1 etc. refer to proposed strategies to address current problems
Note[2]:AN1 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 agriculture sector are given in Table 5.3 for Mauritius.

**Agriculture** - ***Transforming challenges into opportunities*** **(Mauritius)**

**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 |
|---|---|---|---|---|---|
| **A1** | Water Supply and Conservation Support | **A1.1.** Water conservation incentives<br>**A1.2.** Dissemination of micro irrigation systems for efficient water use and management<br>**A1.3.** Floodplain Easements, to maintain agricultural production that is compatible with flood conveyance | H: co-financing<br>G: incentives, capital investment for infrastructure<br>P: co-financing | H: water shortages<br>G: water supply, flood damage<br>P: reduced yield and revenue, water costs | H: food security, employment<br>G: tax revenue<br>P: revenues and income |
| **A2** | Preventing, preparing for, and responding to agricultural invaders, pests and diseases | **A2.1.** Development and up-scaling of locally proven IPDM (integrated pest and disease management) technologies for control of pests and diseases<br>**A2.2.** Decentralised rapid pest and disease diagnosis service (plant clinic)and introduction of insurance | H: O&M cost<br>G: incentives, policy development<br>P: capital and O&M cost | H: N/A<br>G: food imports<br>P: reduced yield and revenue | H: food security and health<br>G: tax revenue from increases production<br>P: revenues and income |
| **A3** | Sustainable land use planning practices | **A3.1.** Encourage community land use (urban and peri-urban farming) against land conversion to urbanization<br>**A3.2.** Explore ways of introducing revenue-generation mechanisms (e.g. carbon trading, certifications) | H: time (agriculture practices)<br>G: awareness raising<br>P: capital investment | H: food expenditure<br>G: food imports<br>P: N/A | H: food security & quality<br>G: carbon revenues, emission reductions<br>P: revenues |
| **A4** | Promote working landscapes with ecosystem services to improve agro-biodiversity | **A4.1.** Technical and financial assistance for the reallocation of agriculture to less critical areas<br>**A4.2.** Promotion and development of sustainable agriculture practices<br>**A4.3.** Promotion of composting and support the use of compost as a substitute to traditional fertilizers | H: composting<br>G: incentives, capital investment for infrastructure, R&D<br>P: co-financing for capital investment, research | H: food expenditure<br>G: food imports<br>P: reduced yield and revenue | H: food security, employment<br>G: national food security<br>P: revenues and income |
| **A5** | Building and sustaining institutional support | **A5.1.** Define a capacity-building framework that will build the capacity of institutions, train their human resources and those of local communities on sustainable agriculture | H: capacity building<br>G: capacity building<br>P: co-financing, capacity building | H: N/A<br>G: policy effectiveness<br>P: reduced yield | H: knowledge and skills<br>G: knowledge and skills<br>P: improved services from staff |
| **A6** | Research, innovation and technology development for bio-farming and communication | **A6.1.** Support biofarming; bring together technologies with agriculture management practices (e.g. through the use of GIS, agro-meteorological stations)<br>**A6.2.** Support the development of appropriate models for communication to transfer and disseminate information on new techniques and technologies including those that address climate change. | H: higher food expenditure<br>G: research-based policy<br>P: co-financing | H: water shortage<br>G: natural resource mgmt. costs<br>P: reduced yield | H: food security<br>G: budget surplus<br>P: revenues and income |

**Rodrigues**

In order to address the challenges posed by climate change impacts and reach national targets of food security and competitiveness in the agriculture sector, RoM through the Rodrigues Regional Assembly, and in collaboration with other relevant entities, could actively support the transition to sustainable agriculture in Rodrigues (Table 5.4).

**Table 5.4: Adaptation policies aimed at reducing the vulnerabilities of the Agriculture sector (TNC, 2016)**

| Strategy | Means of implementation and expected results |
|---|---|
| Reduce vulnerability to climate change | This objective may be achieved by improving water conservation and increasing the efficiency of irrigation. The dissemination of micro-irrigation systems can increase the capillarity of water supply and limit water loss by reducing the distance that water has to travel in the irrigation system. Expanding rainwater harvesting to be reused on-site, rather than allowing it to run off, can decrease the need for pumping water from the aquifer. Technologies for rainwater harvesting include wells, shafts, and boreholes. |
| Develop plans for sustainable land use planning | The plans will help to find a balance among competing uses. Fertile land in rural areas becomes scarcer due to population growth, pollution, erosion, and the effects of climate change. On the remaining land, local users compete to achieve food security. This includes designing laws for zoning, enforcing the abidance to these laws, and investing in education to avoid land encroachment. |
| Prevent and respond to agricultural invaders, pests, and diseases | This aim may be achieved by developing policy for import, maintaining local production, and implementing integrated pest and disease management. This can be realised through integrated pest management (IPM), which aims at integrating appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified, and reduce or minimize risks to human health and the environment. |
| Promote bio-production both for the internal market and for exports. | This goal entails providing technical and financial assistance to local farmers for maintaining traditional production, and increasing reliance on traditional fertilisers and pesticides. Besides, a certification scheme for organic products can facilitate exports to foreign markets, and promote internal consumption if consumers become more aware of the positive externalities of organic products |

The development challenges for Rodrigues in agriculture are similar to those of Mauritius except that it is far less dependent on food imports. Otherwise, the goals and the VAA strategies to address current problems and create new opportunities are very similar. An integrated approach that identifies the intervention options, which turn challenges into opportunities, and the corresponding required investments, and the resulting policy-induced avoided costs and added benefits in the agriculture sector, are given in Table 5.5.

**Agriculture** - ***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 |
|---|---|---|---|---|---|
| **A1** | Water Supply and Conservation Support | **A1.1.** Water conservation incentives<br>**A1.2.** Dissemination of micro irrigation systems (and expand rainwater harvesting) for efficient water use and management<br>**A1.3.** Floodplain Easements, to maintain agricultural production that is compatible with flood conveyance | H: N/A<br>G: incentives, capital investment for infrastructure<br>P: co-financing for capital investment | H: water shortages<br>G: water supply, flood damage<br>P: reduced yield and revenue, water costs | H: food security, employment<br>G: tax revenue<br>P: revenues and income |
| **A2** | Preventing, preparing for, and responding to agricultural invaders, pests and diseases | **A2.1.** Develop policy for imports and (maintaining) local production<br>**A2.2.** Implement integrated pest and disease management | H: N/A<br>G: incentives, policy development<br>P: capital and O&M cost | H: N/A<br>G: food imports<br>P: reduced yield and revenue | H: food security<br>G: tax revenue<br>P: revenues and income |
| **A3** | Sustainable land use planning (zoning) | **A3.1.** Design law for sustainable land use planning and zoning<br>**A3.2.** Enforce abidance to law and avoid land encroachment<br>**A3.2.** Education and awareness raising | H: N/A<br>G: awareness raising<br>P: N/A | H: land use conflicts<br>G: integration of agriculture and pasture<br>P: N/A | H: food security & quality, well-being<br>G: water quality, social cohesion<br>P: N/A |
| **A4** | Promote working landscapes with ecosystem services to improve agro-biodiversity | **A4.1.** Technical and financial assistance for maintaining traditional production (e.g. honey, lemon)<br>**A4.2.** Identification, development and breeding of crop varieties capable of adapting to climate change<br>**A4.3.** Formalize certification for bio production, increasing reliance on tradition fertilizers (e.g. composting) and pesticides | H: composting<br>G: incentives, capital investment for infrastructure, certification<br>P: co-financing for capital investment, certification | H: food expenditure<br>G: food imports<br>P: reduced yield and revenue | H: food security, employment, traditional production<br>G: tax revenue (higher production and access to new markets)<br>P: revenues and income |
| **A5** | Building and sustaining institutional support | **A5.1.** Define a capacity-building framework that will build the capacity of institutions, train their human resources as well as those of local communities on sustainable agriculture | H: N/A<br>G: *capacity building*<br>P: N/A | H: N/A<br>G: *policy effectiveness*<br>P: reduced yield | H: knowledge and skills<br>G: *N/A*<br>P: knowledge and skills |
| **A6** | Research, market development for bio-farming and communication | **A6.1.** Support the development of a bio market (export) for ag products; through awareness raising and facilitating access to market<br>**A6.2.** Support the development of appropriate models for communication to transfer and disseminate information on climate change.<br>**A6.3**. Survey on carrying capacity of cattle | H: N/A<br>G: research and policy<br>P: data collection and analysis | H: water shortage<br>G: natural resource mgmt. costs<br>P: reduced yield, conflict agriculture-cattle | H: food security, employment, traditional production<br>G: water quality, social cohesion<br>P: revenues and income |

### 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 5.6). 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 5.6: 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 5.7 highlights some of the more outstanding opportunities emerging from cross-sectoral linkages for the Agriculture sector. The adoption of bio-, smart and ecological agriculture practices, in addition to the adoption of IPDM techniques, reduces the runoff of chemical fertilizers and pesticides, leading to an improvement of water quality and coastal habitat, and also to a better food quality and health. Further, policies implemented in other sectors can have a positive impact on the agricultural sector. These include the development of climate-resilient infrastructure; and, awareness-raising activities that can increase the demand for organic products, and lead to the creation of a new domestic market as well as to the development of export opportunities.

**Table 5.7: Strategies and opportunities emerging from cross sectoral linkage for the Agriculture sector (TNC, 2016)**

| Mauritius | Rodrigues |
|---|---|
| ***Strategy 1***<br>**Enhance bio, smart and ecological agriculture practices**<br><br>***Direct Cross cutting issues/ benefits***<br>**Reduction of runoff of chemical fertilizers and pesticides**<br>**Improvement of water quality and coastal habitat**<br>**Better food quality and health.**<br><br>***Strategy 2***<br>**Raise awareness to increase the demand for organic products**<br><br>***Direct Cross cutting issues/ benefits***<br>**Creation of a new domestic market as well as to the development of export opportunities.**<br><br>***Other benefits and remarks***<br>Policies implemented in other sectors can have a positive impact on the agricultural sector, including the development of climate resilient infrastructure, which can ensure access to the road network for delivery to markets; | ***Strategies***<br>Improve water conservation and expand rainwater harvesting; implement integrated pest and disease management and promote bio production, increase the number, resilience and height of retaining walls to terraces for crop plantation. |

# 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


- 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.
- Baider, C. et al., 2010. *Status of plant conservation in oceanic islands of the Western Indian Ocean.* Dublin, s.n. Cheke, A. & Hume, J., 2008. *Lost land of the Dodo: the ecological history of the Mascarene Islands.* London: A. & C. Black.
- 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.
- Ministry of Agro-Industry and Food Security, 2016. *Strategic Plan 2016-2020 for the Food Crop, Livestock and Forestry Sectors,* Port Louis: Government of Mauritius.
- Ministry of Environment and Sustainable Development, 2012. *Mainstreaming Climate Change Adaptation in the Development Process in the Agriculture Sector of the Republic of Mauritius in the context of the Africa Adaptation Programme,* Port Louis: Government of Mauritius.
- 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.
- Statistics Mauritius, 2015. *Digest of Demographic Statistics 2014,* Port Louis: Government of Mauritius.
- 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.<br><br>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 20,000$m^3$ 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.<br>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.<br>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.<br><br>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.<br><br>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.<br><br>The coral reefs of Rodrigues which escaped the mass coral-bleaching event of 1997-1998, was affected by the 2016 El-Nino event.<br><br>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 21$^{st}$ 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. | |