Republic of Seychelles

TECHNOLOGY NEEDS ASSESSMENT REPORT - ADAPTATION

[15 February 2017]

SEYCHELLES TECHNOLOGY NEEDS ASSESSMENT REPORT – ADAPTATION

AUTHORS

Prakash (Sanju) Deenapanray, TNA Team Leader (Chapter 1 and Chapter 2; and edited Chapters 3, 4 and 5)
Michele Martin, Adaptation Expert, Coastal Zone (Chapter 3 and Chapter 5)
Herve Barois, Adaptation Expert, Water Sector (Chapter 4 and Chapter 5)

REVIEWERS
Bothwell Batidzirai (Energy Research Centre, University of Cape Town); Gordon Mackenzie (UNEP DTU Partnership, Denmark); Vincent Amelie (Seychelles Meteorological Authority, Seychelles).

TO BE CITED AS

Government of Seychelles. (2017) *Seychelles Technology Needs Assessment Report – Adaptation*: Ministry of Environment, Energy and Climate Change, Seychelles.

This publication is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP DTU Partnership (UDP) in collaboration with the Regional Centre Energy Research Centre, University of Cape Town.

Contents

List of Figures

List of Tables

Acknowledgements

The TNA adaptation team wishes to thank all of the individuals and organisations who took time to participate in the consultative process to identify and prioritise climate change adaptation technologies for the water and coastal zone sectors. These include:

The Ministry of Environment, Energy and Climate Change
The Climate Adaptation and Management Section
Programme Coordination Unit / Ecosystem Based Adaptation Project
Public Utilities Corporation
Seychelles Meteorological Authority
Seychelles Land Transport Division
Sustainability for Seychelles
Marine Conservation Society of Seychelles
Wills Agricole
Vincent Amelie
Marcel Belmont
Marc D'Offay
Franky Dupres
Hendrick Figaro
Elvina Henriette
Andre Labiche
Johan Mendez
Shebrah Michel
Betty Mondon
Pugazhendi Murugaiyan
Steve Mussard
Lemmy Payet
Desire Payet
David Rowat
Nimhan Senaratne
Betty Seraphine
Vanessa Zialor

List of Acronyms

CC	Climate Change
DECC	Department of Energy and Climate Change
DRDM	Department of Risk and Disaster Management
DWSP	Drinking Water Safety Plan
EBA	Ecosystem Based Adaptation
EIA	Environmental Impact Assessment
ENSO	El Niño Southern Oscillation
EPA	Environment Protection Act
GCCA+	Global Climate Change Alliance
GCM	Global Circulation Model
GEF	Global Environment Facility
GIS	Geographic Information System
INDC	Intended Nationally Determined Communication
IRBM	Integrated River Basin Management
IWRM	integrated Water Resources Management
JICA	Japan International Cooperation Agency
LIDAR	Light Imaging, Detection, And Ranging
LWMA	Landscape Waste Management Agency
MCA	Multi Criteria Analysis
MCSS	Marine Conservation Society of Seychelles
MEECC	Ministry of Environment, Energy and Climate Change
Ml	Million litres
MLUH	Ministry of Land Use and Habitat
NCCC	National Climate Change Committee
NCCS	National Climate Change Strategy
NDRMP	National Disaster Risk Management Policy
NGO	Non-Government Organisation
NISTI	National Institute of Science, Technology and Innovation
NRW	Non-Revenue Water
PCU	Project Coordinating Unit
PSC	Project Steering Committee
PUC	Public Utilities Corporation
RCP	Representative Concentration Pathway
RWH	Rainwater Harvesting
SCCF	Special Climate Change Fund
SIDS	Small Island Developing States
SLR	Sea Level Rise
SLTA	Seychelles Land Transport Agency
SMA	Seychelles Meteorological Authority
SNC	Second National Communcation
SR	Seychelles Rupee
SSDS	Seychelles Sustainable Development Strategy
SSP	Seychelles Strategic Plan
TNA	Technology Needs Assessment
TNC	Third National Communication
TWG	Technical or Technology Working Group
UDP	UNEP DTU Partnership
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNISEY	University of Seychelles

US$	United States Dollar
WEAP	Water Evaluation And Planning
WIO	Western Indian Ocean

Executive Summary

The Seychelles prioritised the coastal zone and water as priority sectors deserving technical assistance under the Technology Needs Assessment (TNA) project. The choice of these sectors is squarely aligned with several factors, including among others: their importance to society and economy; their vulnerabilities to climate change; alignment with government policies and strategies, including the adaptation contribution in the Seychelles Nationally Determined Contributions that was submitted in light of the Paris Agreement. Only two priority sectors were chosen because of financial and time resource constraints. While noting that other sectors also deserve technology transfer to support resilience building in the face of climate change, it is proposed that the TNA process be extended to additional vulnerable sectors during the implementation of the Third National Communication (TNC).

Technology working groups (TWGs) were set up bearing in mind local expertise in technologies to address coastal flooding and erosion, and diversification and end-use efficiency in the water sector. The members of the TWGs were drawn from government, civil society, academia and the private sector. Different types of stakeholder engagement approaches were utilised, including: a national workshop to introduce the entire TNA process to stakeholders and to initiate the process of technology identification and prioritisation using the Multi-criteria Analysis (MCA) decision making framework; working sessions of the TWGs; bilateral meetings; and communications by email. The last two approaches were particularly useful given the fact that not all stakeholders were able to attend working sessions of the TWGs.

The participative and inclusive approach adopted by the TNA project ensured that members of the TWGs were regularly updated on the progress of the technology identification and prioritisation process. Technology fact sheets (TFS) were also developed in close consultations with the members of the TWGs and used in the technology prioritisation process.

MCA calculators were customised for the TNA project, and the open source tools were made available to all stakeholders. The criteria and indicators used for the MCA exercise for the coastal zone sector were customised using the MCA4Climate framework as the starting point. The sensitivity of technology ranking on weights was carried out for three different sets of weights. The weights were assigned by the members of the TWGs, and were found to have no bearing on the rankings of the top three prioritised technologies (for both sectors), implying that the MCA results were robust.

The top three ranked coastal adaptation technologies are:

1. Mapping
2. Wetland restoration
3. River outlet improvement

However, because the government is already investing heavily in river outlet improvement and the expertise already exists in the country, it was proposed to instead adopt dune restoration as the third prioritised technology. The revised list of prioritised coastal adaptation technologies that will be used for carrying out barriers analysis and development of technology action plans for the coastal zone sector are:

1. **Mapping** – This technology includes flood mapping, mapping of coastal ecosystems (using LIDAR and drones), bathymetry and current mapping to better understand movement of waves and sand offshore in order to allow for better planning of coastal restoration and protection measures. Mapping is generally considered to be a basic necessity for the successful implementation of all other technologies for protection of the coastal zone. It can be implemented quite easily, given that several measures were put in place for overcoming the financial and human capacity barriers that the technology faces;

2. **Wetland restoration –** wetland restoration helps to address coastal flooding (precipitation, SLR, storm surges). In some places, wetland restoration would need to be implemented alongside other measures such as river outlet improvement and setbacks, as well as improving current laws and policies regarding wetland protection. There is great potential for working with private landowners and hotels and communities to restore and improve the natural functioning of coastal wetlands.

3. **Dune Restoration** –Dune restoration has been tried to some extent by the government but needs further development. This technology is of great interest due to the added social benefits of providing additional space for people to enjoy the beaches, as well as an opportunity for revegetation along coastal areas. There is need for more research to design dune restoration projects that are effective and tailored to the specific locations where they are needed, with input from an improved mapping and modelling capacity in the country. Furthermore, dune restoration can be combined with other soft and hard technologies, including river outlet improvement and low seawalls.

The prioritised water sector adaptation technologies are:

1. **Rooftop rainwater harvesting with water treatment and safe storage**: This climate change adaptation technology is based on encouraging each household to have a rainwater harvesting system with appropriate water treatment and water storage which is currently not universally used in the Seychelles (only 4.7 % of households are equipped with technology). This technology is a priority because it has potential for scaling up and can contribute significantly to reducing climate vulnerability at the household level, primarily by diversifying household water supply; and by increasing resilience to water quality degradation.

2. **Water efficient appliances**: The residential sector is the highest end-use sector in Seychelles. Residential water conservation efforts can make a positive contribution to reducing pressure on water resources. However, the market penetration of water efficient appliances is low and their utilization is poor. Encouraging each household to have water efficient devices with the appropriate framework is a national priority to reduce pressure on water resources and increase climate resilience of the population.

3. **Ground surface rainwater harvesting**: Lack of adequate water supply during drought and seasonal dry periods can have a significant economic impact in the agricultural sector. Ground surface runoff water is important in the Seychelles because of its geology, topography and rainfall patterns. This technology based on improving storage of surface runoff water by building gabion structures is a priority for the agricultural sector to have a constant and regular water supply, thereby minimising the impact of climate change on crop and livestock production and improving the food security in the Seychelles.

Chapter 1 Introduction

1.1 About the TNA project

Technology transfer has been under focus since the Rio Summit in 1992, where issues related to technology transfer were included in Agenda 21 as well as in Articles 4.3, 4.5 and 4.7 of the UNFCCC Convention. These were subsequently discussed in COP 1 in Berlin and COP 4 in Buenos Aires with Decision 2/ CP4 requiring GEF to provide funding to developing country Parties to enable them identify and submit to the COP, their prioritised technology needs, especially as concerns key technologies needed in particular sectors of their national economies conducive to addressing climate change and minimising its adverse effects. Following this, GEF provided funding to 92 countries between 2000 and 2004 for the first round of Technology Needs Assessments (TNAs) through its enabling activities phase II (also known as "top-ups") programme. The processes followed by various countries in the first round of TNA were diverse and, for the most part, the end results lacked implementable actions. In response to COP 13 request, GEF proposed the Poznan Strategic Program on Technology Transfer, which was endorsed by COP 14. It consists of three funding windows; (i) technology needs assessments (TNAs); (ii) piloting priority technology projects; and (iii) dissemination of successfully demonstrated technologies.

In 2009, a new round of TNAs (TNA Phase I) commenced in 36 developing countries and was successfully concluded in April 2013. The current Global TNA project (TNA Phase II), deriving from window (i) of the Strategic Program on Technology Transfer, is designed to support 25 more countries to carry out new or improved Technology Needs Assessments within the framework of the UNFCCC. The assessments will involve amongst others in-depth analysis and prioritisation of technologies, analysis of potential barriers hindering the transfer of prioritised technologies as well as issues related to potential market opportunities at the national level. National Technology Action Plans (TAPs) agreed by all stakeholders at the country level will be prepared consistent with both the domestic and global objectives. Each TAP, which will outline essential elements of an enabling framework for technology transfer consisting of market development measures, institutional, regulatory and financial measures, and human and institutional capacity development requirements, will also include a detailed plan of action to implement the proposed policy measures and estimate the need for external assistance to cover additional implementation costs. Thus, the detailed plan of action will serve as the base for the subsequent preparation of fundable project ideas.

Targeted training and supporting materials related to methodology for prioritisation of technologies, market assessment, access and links to data on technologies have been developed and tested and made available to all participant countries. Experiences gained during the project implementation will be shared amongst participating countries to enhance cross-country learning. The main objectives of the project are:

1. To identify and prioritize through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities (TNA).
2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies.
3. To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in the participant countries.

The ultimate aim of the TNA project is to use a robust process and methodology to enhance the preparedness of Seychelles to leverage international climate finance for adopting or scaling up environmentally sound technologies (ESTs) to increase its resilience in the face of the impacts of climate change. Further, the TNA process will serve as a means to support the implementation of Seychelles Intended Nationally Determined Contribution (INDC) (Republic of Seychelles, 2015a).

1.2 Existing national policies related to technological innovation, adaptation to climate change and development priorities

The Seychelles consists of over 115 islands of which some 40 are granitic and the rest coral with a total human population of about 84,600 (NSB, 2007 – '2006 population estimates'). The four main inhabited granitic islands in order of size are Mahé, Praslin, Silhouette and La Digue, and vary in age from some 650 to 750 million years old. The Seychelles islands are located within 4^o and 9^o South of the equator, and with a total area of 455.3 km^2. All the islands put together result in a coastline of about 491 km (The World Fact Book, 2008). The majority of the islands are surrounded by coral reefs with an area of about 1,690 km^2 (Payet, 2004), many of which were affected by the mass coral bleaching event of 1998 which was caused by abnormally warm waters (Linden et al., 1999). More than 90% of the population and all economic activities are located on the narrow coastal plateau of Mahé Island, at an average elevation of 2 m above sea level.

Small island developing States (SIDS) were recognized as a special case for both environment and development in Chapter 17(G) of Agenda 21 (UN, 1992). The grounds for this special consideration relates to the inherent vulnerabilities to which SIDS are exposed, including their small size, limited and narrow resource bases, geographic dispersion, isolation from markets, susceptibility to climate change and natural disasters, and exposure to external shocks from such sources as energy, financial and economic crises. Although, it is classified as an upper middle-income country, the Seychelles has the same inherent vulnerabilities resulting in key weaknesses in human, scientific, financial, technical, technological and institutional capacity.

The Seychelles is economically, culturally and environmentally vulnerable to the potential effects of climate change and associated extreme events. Vulnerability characteristics such as concentration of development on narrow coastal zones, non-resilient populations and ecosystems make the Seychelles extremely sensitive to climate change and its associated impacts. The impact of climate change on coastal livelihoods as a result of sea level rise, storm and tidal surges, extreme sea-surface temperatures, and coastal flooding will have serious consequences for livelihoods in the Seychelles.

In response to those challenges, government, the private sector and non-governmental organisations are already implementing a number of activities enshrined in the Environment Management Plan 2000 to 2010 and the Seychelles First National Communication. An increase in extreme weather events prompted government to strengthen its national meteorological services and establish a fully-fledged institution for disaster prevention and response. The Climate and Environmental Services Division (CESD) was established in 2008, which incorporated the National Meteorological Services (NMS), the Environment Engineering Section (EES) and Programme Management Section (PMS) to enable focus on climate change issues. The Second National Communication (SNC) process was primarily focused on strengthening the technical and institutional capacities to mainstream the effect of climate change into national policies and development guidelines of Seychelles; and it has studied four major sectors - Fisheries Sector, the Agricultural Sector, the Water Sector and the Coastal Zone Sector. The analyses carried out in the SNC already hinted towards the priority areas for adaptation in the Seychelles.

Although the policies and strategies that are discussed below do not make explicit reference to technology transfer, their implementation will necessarily involve the transfer and diffusion of environmentally sound technologies in a wide array of their three components, namely hardware, software and/or orgware (Nygaard and Hansen, 2015).

The ***Seychelles National Climate Change Strategy*** (NCCS) 2009 (Government of Seychelles, 2009) was formulated to provide a coherent and consolidated response to climate change. Central to the strategy is the mainstreaming of climate change into sustainable development as a national cross-sectoral programme addressing matters of policy, institutions, capacity building and civil society involvement. The NCCS formulated a vision for addressing climate change in the Seychelles (Government of Seychelles, 2009):

"*To minimise the impacts of climate change through concerted and proactive action at all levels of society*"

Five strategic objectives were proposed to achieve this vision:

1. To advance our understanding of climate change, its impacts and appropriate responses.
2. To put in place measures to adapt, build resilience and minimize our vulnerability to the impacts of climate change.
3. To achieve sustainable energy security through reduction of greenhouse gas emissions.
4. To mainstream climate change considerations into national policies, strategies and plans.
5. To build capacity and social empowerment at all levels to adequately respond to climate change.

A SWOT analysis of the adaptive capacity of the Seychelles was carried out in order to inform the development of an action plan to achieve the strategic objectives of the NCCS.[1] The results of the analysis are shown in **Figure 1**. The action plan of the NCCS is summarised in **Annex I**.

Strengths	**Weaknesses**
• A number of existing laws, regulations & policies invoke adaptation approaches • Reliable institutional structures in place • Emerging community-based structures • Strong NGO and civil society involvement in biodiversity issues • Voluntarism, cooperative arrangements and collaborative processes appear well developed • High level of public awareness on climate issues • Strong government support to implement adaptation measures • Strong health and education systems in place	• Poor enforcement and lack of consistent implementation of policies and laws • Lack of capacity and knowledge to address emerging issues • Limited financial resources for adaptation • Lack of coordination and communication between certain sectors • Poor involvement of the private sector in adaptation activities • Insufficient training and capacity building opportunities • Physical isolation of the country • Insufficient external project funding for adaptation
Opportunities	**Threats**
• Increased number of training and capacity building for adaptation at international level • Role of the media in building awareness and action for adaptation • Further expansion of CBOs and NGOs involved in adaptation activities • Greater involvement of the community • Involve the private sector in adaptation planning and financing • Increased donor funding.	• International climate taxes impact on tourism and reduce national capacity to adapt • Loss of employment and economic returns as a result of damaged facilities • Continued inappropriate development in high risk areas, especially from sea level rise and landslides. • Ignoring policies and guidelines • Bureaucracy, especially in decision-making • Loss of human resource capacity • Risk of global crises (e.g. food, energy, financial) undermining adaptation efforts.

Source: National Climate Change Strategy

Figure 1. SWOT matrix on the adaptation capacity of the Seychelles.

The ***National Disaster Risk Management Policy*** (NDRMP) (Government of Seychelles, 2014) seeks to outline a comprehensible, transparent and inclusive policy on disaster risk management appropriate for the Government of the Republic of Seychelles within the four phases of disaster risk management continuum. The goal of the Policy is to contribute to the attainment of sustainable development in line with Seychelles Vision 2020 through strengthening of national capacities to reduce risk and build community resilience to disasters. The National Disaster Risk Management Policy aims to:

- Minimise the loss of human life, property, livelihood and damage to the environment from hazards of natural, geological, technological, biological and ecological origin;
- Advocate an approach to disaster risk management that focuses on reducing risks especially to those sections of the population who are most vulnerable;

[1] Similar exercises were carried out on the mitigation capacity of the Seychelles, which is discussed in the Seychelles Technology Needs Assessment Report – Mitigation, and capacity issues for climate change in the Seychelles.

- Advocate for a shared awareness and responsibility to reduce disaster risk in homes, communities, places of work and in society generally;
- Give effect to the application of co-operative governance on issues concerning disasters and disaster risk management among all levels of government and allocate responsibilities in this regard to the relevant stakeholders:
- Facilitate the involvement of the private sector, non-governmental organisations, communities and volunteers in disaster risk management; and to
- Facilitate partnerships in this regard between organs of state and the private sector, non-governmental organisations and communities.

The Policy sets out to erase the perception that disasters are rare occurrences managed by emergency rescue and support services to an improved capacity for early warning and for tracking, monitoring/surveillance and disseminating information on phenomena and activities that trigger events (natural and man-made hazards).

The NDRMP articulates the establishment (with clearly defined mandates and roles and responsibilities of all stakeholders) of the National Disaster Risk Management System (NDRMS) comprising of the following inter-sectoral structures (Government of Seychelles, 2014):

- National Disaster Risk Management Committee
- Division of Risk and Disaster Management
- National Platform for Disaster Risk Reduction
- National Vulnerability Assessment Committee

The Policy also accounts for the mechanism for funding disaster risk management, and provides details for interventions in five key performance areas. The five areas are (Government of Seychelles, 2014):

- Key Performance Area 1: Establishing sound, integrated and functional legal and institutional capacity for total disaster risk management in Seychelles.
- Key Performance Area 2: Improving risk identification, assessment and monitoring mechanisms in Seychelles.
- Key Performance Area 3: Reducing the underlying risk and vulnerability factors by improving disaster risk management applications at all levels.
- Key Performance Area 4: Strengthening disaster preparedness for effective response and recovery practices at all levels.
- Key Performance Area 5: Enhancing information and knowledge management for disaster risk management.

The ***Seychelles Strategic Plan 2015 - 2040*** (Government of Seychelles, 2015b) sets out the long term spatial planning framework for the country up to 2040. It includes spatial policies relating to:

- priorities for economic growth and development;
- scale and distribution of new housing;
- protection of the marine and terrestrial environment and biodiversity;
- protection of the built and historic environment;
- tackling climate change and safeguarding natural resources; and
- priorities for infrastructure provision.

The Strategic Plan has been aligned with the main development agenda set out in the National Development Strategy (NDS) 2015 - 2019 (Government of Seychelles, 2015c) and the Seychelles Sustainable Development Strategy (SSDS) 2012-2020 (Government of Seychelles, 2011a). Consequently, the NDS and the SSDS are not reviewed here. The development of a sustainable blue economy[2] will be of critical importance to the development of the Seychelles Strategic Plan and the achievement of the objectives set out in the National Development Strategy.[3] The result of integrating the blue economy in the Strategic Plan has been an increased awareness of the oceans as 'development spaces' where spatial planning can be used to promote sustained, environmentally-sound and socially inclusive economic growth.

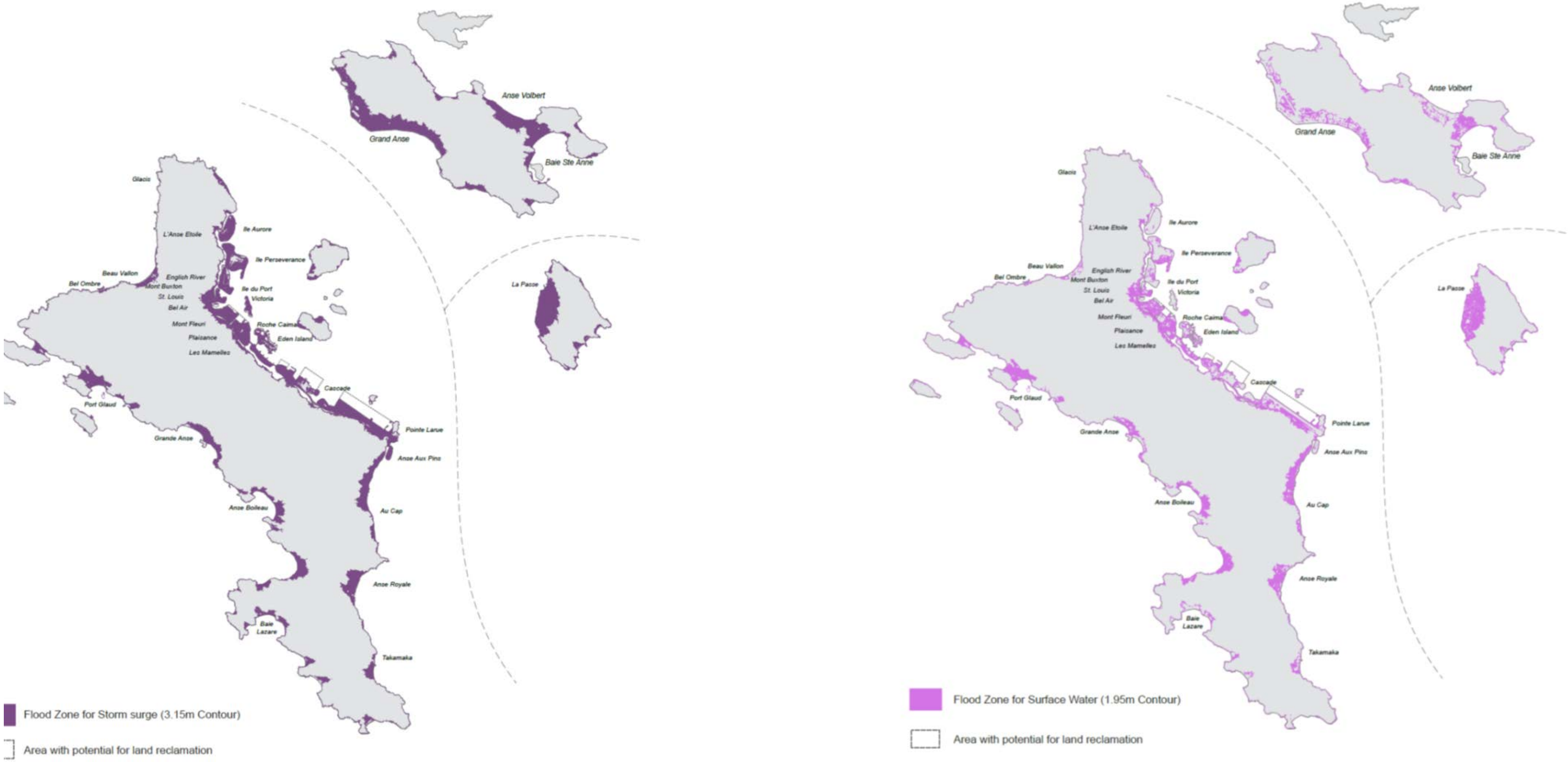
The Strategic Plan notes that some climate change is inevitable. The balance of probabilities is that Seychelles is likely to feel the effects of sea level rise and more extreme weather events. There will also be an increased probability of flooding and a need to cope with the greater consequences when it does happen. Sea levels will be higher; there will be more frequent and higher tidal surges; and the potential for more surface water flooding. It is likely that a significant proportion of infrastructure will be at increased risk from flooding. A further problem arising from climate change will be an increasing shortage of water. Seychelles is already 'water stressed' due to the infrequencies of rainfall, lack of suitable water storage and under certain conditions, water consumption outstripping available supply. This is all within the context of per capita water usage increasing. The current and projected climate changes are discussed in section 1.4.1 below.

In order to adapt to the impacts of climate change, adaptation measures have been proposed in the Strategic Plan. These are discussed further in section 1.4.2. The Strategic Plan provides maps and plans for areas (inhabited, built infrastructure, critical ecosystems) that are prone to natural disasters including among others coastal erosion, storm surges, and flooding. **Figure 2** shows the flood risk maps arising from storm surges (left) and surface water during heavy precipitation events (right) for the three mostly inhabited island of Seychelles. The maps provide priority areas for interventions regarding flood proofing of coastal areas arising from natural hazards. The freshwater water supply and distribution system is illustrated in **Figure 3** for the island of Mahé. It shows the locations of existing and potential water supplies (dams and desalination plants) as well as water supply diversification using rainwater harvesting. The map provides a framework for integrated water resources management with the main objective of increasing the resilience of Seychelles in the face of water scarcity. The measures proposed to deal with the vulnerability to water shortages or floods are discussed in section 1.4.2.

---

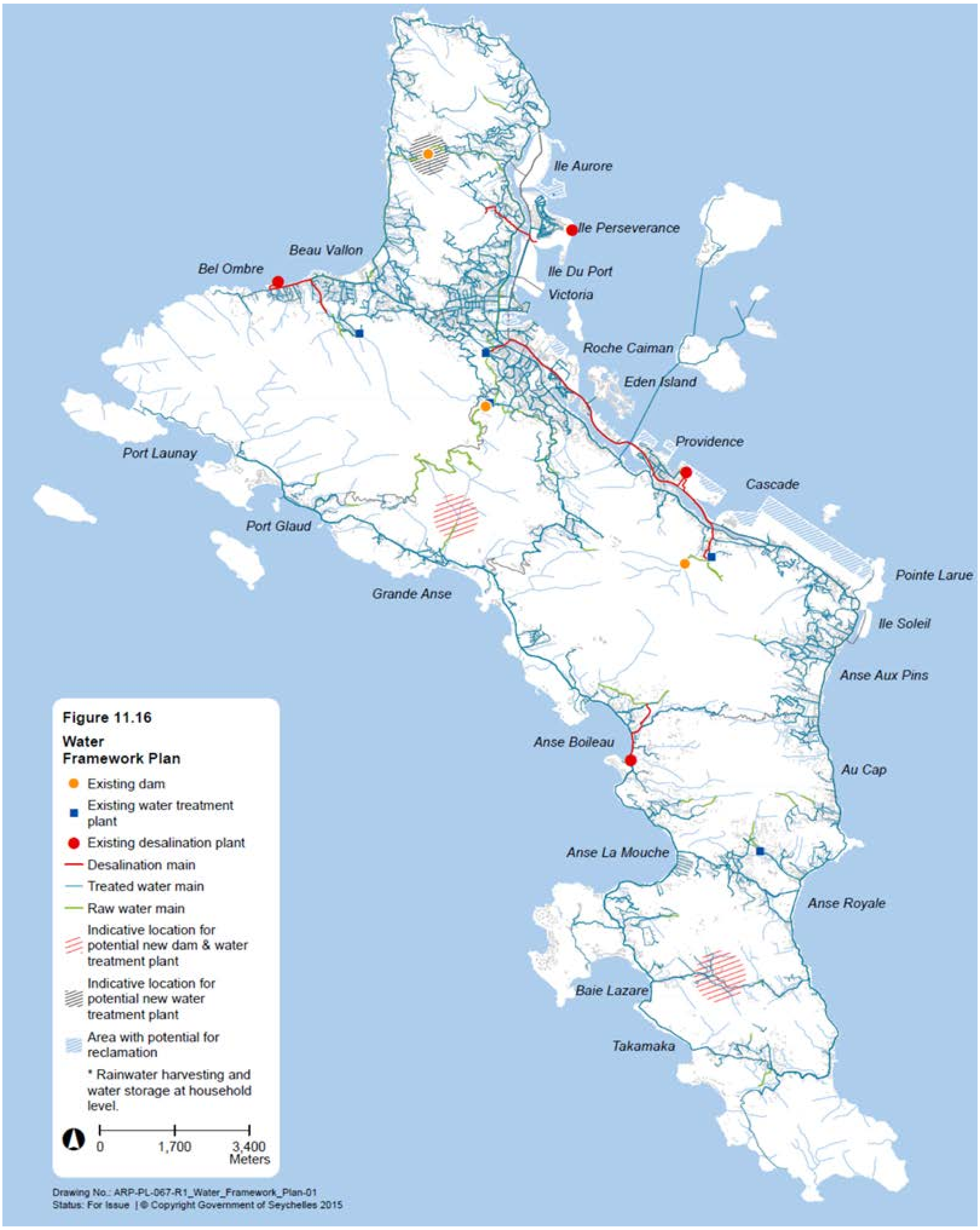
[2] The concept of the 'blue economy' originates from the 2012 UN Conference on Sustainable Development and seeks to utilise the opportunities for development provided by maritime and coastal assets in a sustainable way to reduce carbon emissions, pollution and environmental degradation; promote greater energy efficiency; and protect biodiversity, whilst achieving economic growth through enhanced employment opportunities and improved social welfare.

[3] The main objective of the National Development Strategy is to double country's GDP between 2007 and 2017. This growth will continue to be based on the tourism and fisheries sectors, but will also depend on innovation in the development of the 'blue economy' and of the 'green economy' – i.e. maintaining a pristine natural environment and increasing the use of renewable energy.



Source: Government of Seychelles, 2015b

Figure 2. Flood risk map from storm surge (left); Flood risk map from surface water (right).



Source: Government of Seychelles, 2015b

Figure 3. Water framework plan for island of Mahé.

The Seychelles ***Intended Nationally Determined Contribution*** (INDC) (Government of Seychelles, 2015a) makes an implicit link with several UNFCCC-related initiatives including the TNA project regarding the transfer and diffusion of environmentally sound technologies for both climate change mitigation and adaptation. In the adaptation section of the Seychelles INDC, the following is stated (Government of Seychelles, 2015a):

> "In many cases, Seychelles lacks the technological capacity to undertake effective research on climate change modelling and risks, monitoring of climate change impacts and implementation of adaptation measures. In some cases, the knowledge may be there but the technology is prohibitively expensive, e.g. in terms of diversifying away from fossil fuels for renewable energy, or protecting critical infrastructure. The way forward for these challenges will also include alliances with overseas partners including donors, a trend that has already been initiated by several government agencies including Seychelles Meteorological Service, the Department of Risk and Disaster Management, and the Ministry of Environment, Energy and Climate Change. The National Institute for Science, Technology and Innovation will reinforce the technological capacity to undertake effective research on climate change-related issues."

1.3 Vulnerability assessments in the country

Recent studies conducted in Seychelles, by research partners from Cuba (Mendez et al., 2013) and Japan (JICA, 2013), highlighted that much of the human activity is concentrated around the low-lying, coastal areas which are at the highest risk of flooding from heavy rainfall, storm surges, and sea level rise during the longer term. These findings have been reaffirmed in a recent UNISDR report (Zarine et al., 2015) revealing that most disasters occurring in Seychelles were related to storms, floods, rain and landslides. It has recommended that future planning should focus on losses from flooding and landslides which also caused the greatest economic losses. The report also noted concern about *lack of clear policy on the protection of critical infrastructure* in the country, such as roads, ports, government buildings, energy generation, water distribution and sewerage systems.

A Vulnerability Resilience Profile (VRP) (Adonis and Zarine, 2014) exercise undertaken in Seychelles revealed that Seychelles was most vulnerable and least resilient in terms of biodiversity resources and sustainable consumption and production (both with significant implications for climate change adaptation), the tourism industry (the country's crucial economic sector) and food security. Other areas of concern were sea level rise, coastal and marine resources, water security and energy security. The VRP is a tool designed predominantly for allowing SIDS to report on their progress towards the implementation of sustainable development strategies formulated under the UN system, such as the SAMOA Pathway (UN, 2014). The results of the VRP for Seychelles are summarised in **Table 1**.

Table 1. Vulnerability and Resilience Profile of Seychelles.

Issue	**Vulnerability** (most vulnerable = 5)	**Resilience** (highest resilience = 5)
Climate change and sea-level rise	4.5	2.5
Natural and environmental disasters	4.3	3.4
Management of wastes	3.35	2.5
Coastal and marine resources	4.7	2.6
Freshwater resources	4.4	2.5
Land resources	4.6	3.0
Energy resources	4.6	2.6
Tourism resources	4.2	3.5
Biodiversity resources	4.3	2.1
Sustainable production and consumption	4.7	2.4
Health	4.4	3.0

Source: Adonis and Zarine, 2014

The ***Seychelles INDC*** (Government of Seychelles, 2015a) has reported the vulnerabilities of Seychelles to climate change. These are:

- Critical Infrastructure (roads, ports, government buildings, electricity, water and sewerage management systems);
- Tourism (in proximity to the coast or in areas vulnerable to flooding and landslides);
- Food Security (currently reliant on food imports, and need support for local sustainable and climate-smart agriculture and fisheries efforts);
- Coastal and Marine Resources (considering the aims of the *Blue Economy* and *Seychelles Strategic Plan 2015)*;
- Water Security (particularly considering issues of storage and distribution);
- Energy Security (particularly considering the reliance on fossil fuels);
- Health (particularly addressing the burden placed on high-density populations in the coastal areas and general vulnerability to climate-sensitive diseases);
- Waste (particularly for landfill sites in high risk, coastal locations); and
- Disaster preparedness (particularly addressing the need for more research to understand climate change impacts, and resources to predict, prevent and respond to disasters).

1.4 Sector selection

The two priority adaptation sectors for Seychelles are the Coastal Zones and Water sector. As discussed in the previous section, both sectors are vulnerable to disasters. Seychelles is particularly exposed to sea-related natural disasters because of its disproportionately high ratio of total coastline to its total surface area (~1.08 km^{-1}). This ratio is 0.68 km^{-1} and 1.13 km^{-1} for Mahé and Praslin that are the two mostly populated islands of Seychelles (JICA, 2013, pg. 30).[4] Further, virtually all socio-economic activities take place on the narrow coastal plateau of Mahé Island, at an average elevation of 2 m above sea level.

1.4.1 An Overview of Expected Climate Change and its Impacts in Sectors Vulnerable to Climate Change

The Second National Communication, SNC (Government of Seychelles, 2011b) is the most recent official document that relates the current and future climate changes and their sectoral impacts. The SNC also studied the five most vulnerable sectors, namely: the coastal zones, water resources, agriculture, fisheries and health sectors. More recently, dynamic downscaling has been carried out for the island of Mahé using PRECIS,[5] therefore providing the most up to date climate change results for Seychelles (Seychelles Meteorological Authority and Météo France La Reunion, 2016). While the full details and results of the downscaled modeling will be reported in the Third National Communication (TNC), the main findings are discussed below.

The climate change results reported in the SNC were derived from Global Circulation Models with 5 degree resolution – i.e. ~500 km x 500 km resolution (Government of Seychelles, 2011b, pg.192). In short, the results did not provide the spatial resolution necessary to reveal local climate impacts at the scale of an island like Seychelles. For instance, the main inhabited island of Mahé is 26 km long and 17 km wide.[6] The differences between the climate change results reported in the SNC and those

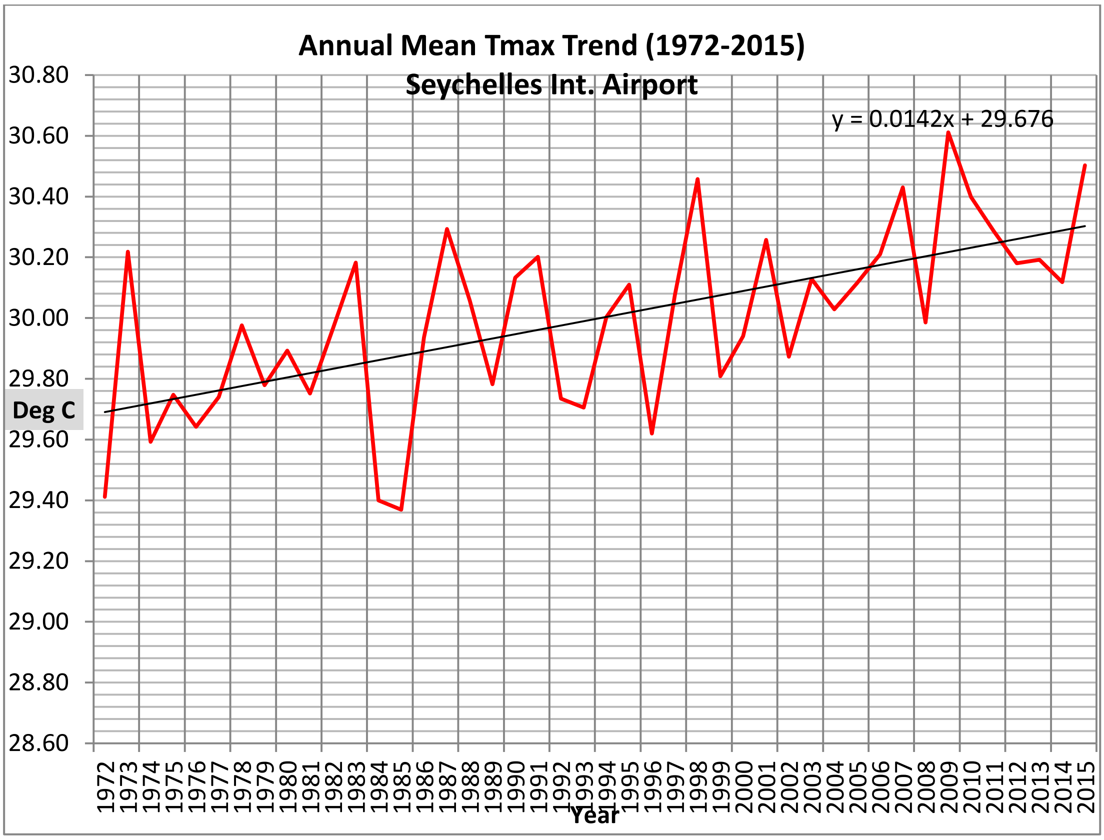
[4] For comparison, the ratio of coastline to surface area of Mauritius, Madagascar and Australia are 0.089 km^{-1}, 0.0083 km^{-1}, and 0.0034 km^{-1}, respectively. Data published in The World Fact book was used. The data can be found at https://en.wikipedia.org/wiki/List_of_countries_by_length_of_coastline - accessed 9 September 2016.
[5] http://www.metoffice.gov.uk/research/applied/applied-climate/precis - accessed 13 September 2016.
[6] https://en.wikipedia.org/wiki/Mah%C3%A9,_Seychelles – accessed 13 September 2016.

derived from downscaled modeling reported below can be attributed to the differences in spatial resolution.

Climate variability and trends

Air temperatures

The maximum and minimum temperatures have increased since 1972. It is reported in the SNC that the most significant warming trend is reflected in the minimum temperatures where there has been an increase in days of warm nights as compared to days of cool nights (Government of Seychelles, 2011b). Data recorded at the Seychelles International Airport between 1972 and 1999, revealed maximum temperature anomaly with rates of 0.0149, 0.0032 and 0.0096°C per year for the December, January and February (DJF), June, July, August (JJA) and the annual temperature time series respectively (Government of Seychelles, 2011b). The data shown in **Figure 4** reveals an annual increase in the maximum annual mean temperature of 0.0142°C per year between 1972 and 2015. The increases in the monthly mean maximum temperature in April and December (not shown here) have been found to be 0.0185 and 0.0201°C per year over the same time period. The new results show that the increase in temperature is higher than what was previously reported.



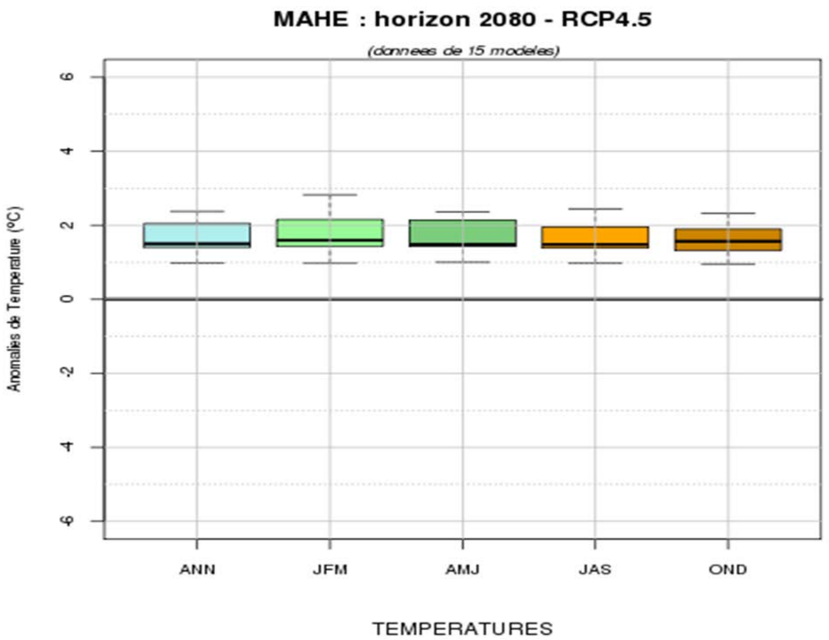
Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

Figure 4. Annual mean maximum temperature at Seychelles International Airport, 1972 - 2015.

The results of temperature anomalies for RCP4.5[7] are shown in **Figure 5** for 15 downscaled Global Circulation Models (GCMs). The temperature anomalies are for the simulated 2066-2095 climate compared to the 1971 – 2000 climate. The increase in mean annual temperature is expected to be

[7] Representative Concentration Pathway for a radiative forcing of 4.5 W/m^2.

between ~1.5°C and 2°C in 2080, and the projected increase in temperature fairly similar across the four quarters analysed.[8] The mean annual temperature anomalies are projected to lie between 2.6°C and 3.5°C for RCP8.5 (not shown). Likewise, the projected increase in mean temperature is similar across the four quarters. The results shown in **Figure 4** and **Figure 5** are in qualitative agreement. There is also qualitative agreement between the results shown in **Figure 5** and those reported in the SNC, albeit that the currently observed (**Figure 4**) and projected temperature increases (**Figure 5**) are higher than the results reported in the SNC.

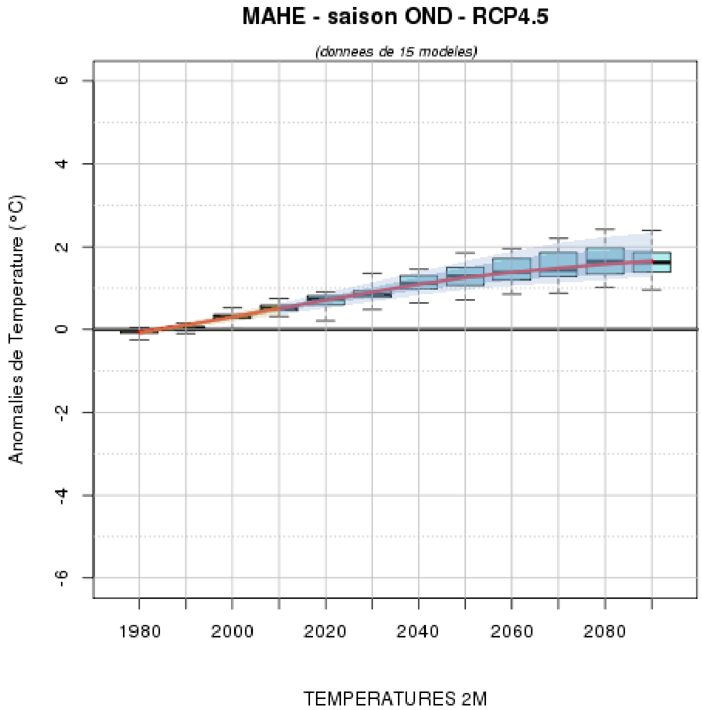


Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

Figure 5. Annual and breakdown of temperature anomalies for simulated climate 2066 to 2095 for RCP4.5.

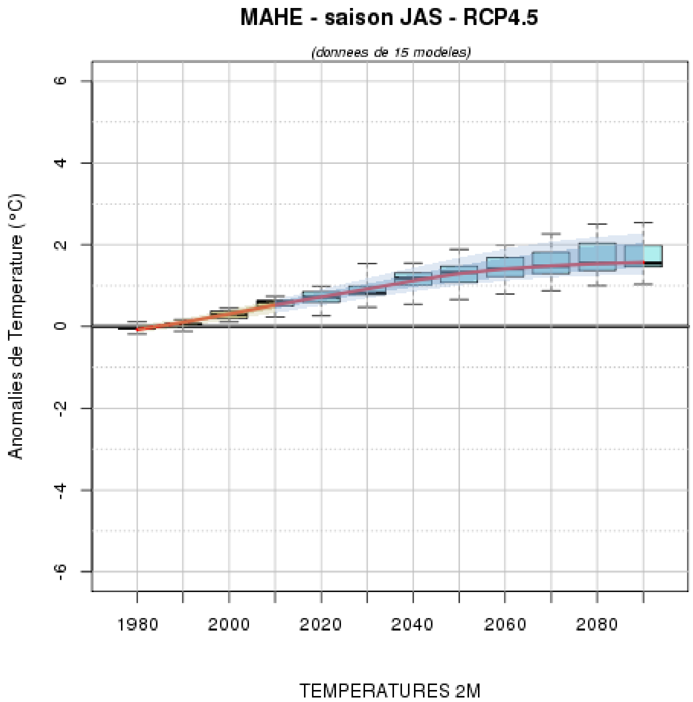
The mean temperature anomalies for OND and JAS are shown in **Figure 6** and **Figure 7**, respectively, for the period covering 1980 and 2100. The results show a clear increase in temperature anomalies with decreasing return. The downscaled results for RCP4.5 reveal an increase of approximately 1°C in temperature anomalies in 2030 for both the wet (OND) and dry (JAS) seasons. By the end of century, the increase in temperature anomaly is expected to be marginally higher in OND than in JAS. As expected, the variances between the 15 models outputs increase with time.

[8] ANN: Annual; JFM: January, February, March; AMJ: April, May, June; JAS: July, August, September; OND: October, November, December. It is pointed out that the quarter periods used in the downscaling exercise are not the same as those used in the SNC. There is a difference of one month between each quarter used in the downscaling and SNC.



Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

Figure 6. Mean OND temperature anomalies for RCP4.5: 1980 – 2100.



Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

Figure 7. Mean JAS temperature anomalies for RCP4.5: 1980 – 2100.

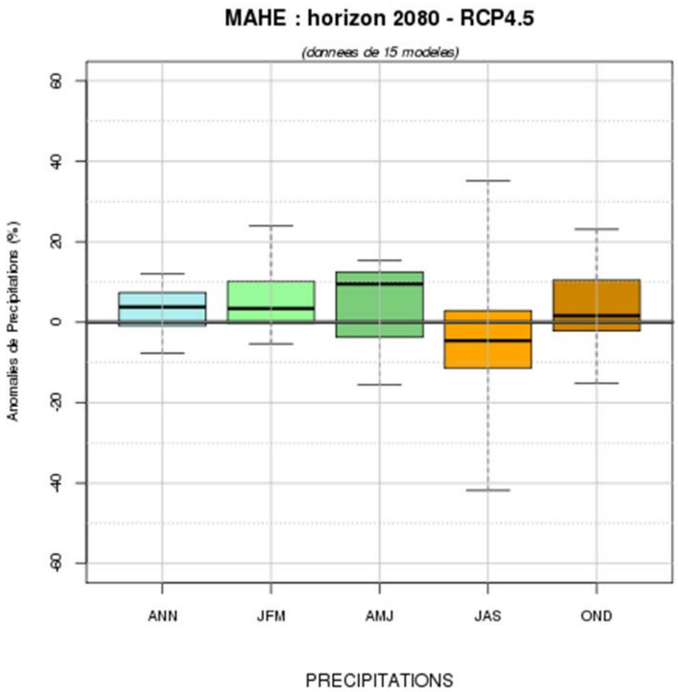
<u>Precipitation</u>

Temporal rainfall changes were analysed for DJF, JJA and the annual time series for data collected at the Seychelles International Airport between 1972 and 2006. The linear seasonal and annual anomaly trends were found to be 0.6423, 2.0286 and 13.774 mm per year for DJF, JJA and annual time series respectively (Government of Seychelles, 2011b). The JJA dry season was observed to receive ~3 times more rainfall than the rainy season, thereby exhibiting wetter conditions compared to the 1972-90 period.

The climate change scenario projections in the SNC were interpreted as informing us that rainfall was more likely to increase in the southern summer and to decrease during southern winter time. The results may be summed up as follows (Government of Seychelles, 2011b, pg.193):

- Likely extremes of low rainfall in the dry season with a deficit of -12.7 % (-9.9 mm) in rainfall for the year 2025, and a decrease of -36.3 % (-31.1 mm) in the year 2100;
- In contrast, the likely extremes of wet conditions are likely to be characterised by an increase of +5.9 % (+19 mm) for the year 2025, +9.3 % (+25.4 mm) for the year 2050 and +12.4% (+38.6 mm) for the year 2100.

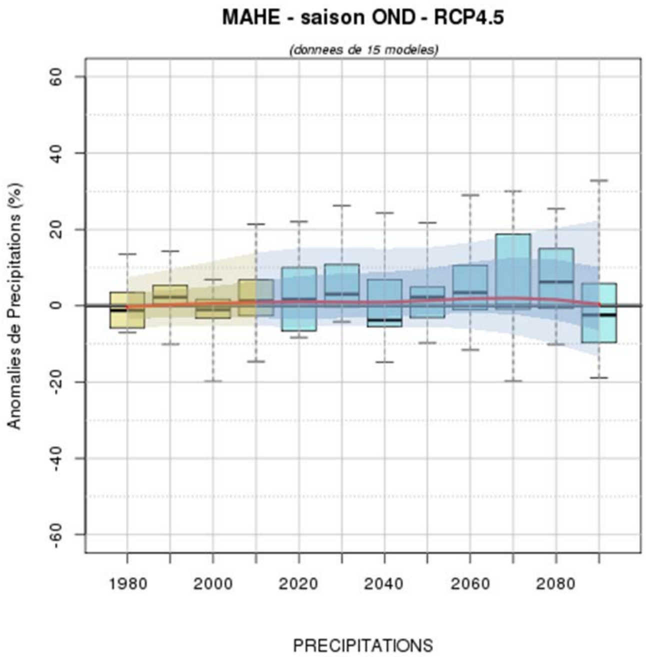
The rainfall anomalies obtained from downscaled climate modeling are shown in **Figure 8** for RCP4.5. The simulated climate is for the period 2066 to 2095 while the reference period is 1971 to 2000. Unlike the consistent increase in temperature, rainfall patterns show wide variations across the different quarters. Also, the quarterly rainfall anomalies have larger ranges that the narrower ones observed for temperature anomalies. These observations suggest that climate-driven changes in rainfall have to be interpreted with more caution. There is an overall increase in annual precipitation of around 4% compared to the 1971 – 2000 climate. In concordance with the projections reported in the SNC, the dry season (JAS) appears to become drier, albeit with large variances between the models. These variances are larger for RCP8.5 (not shown). AMJ is expected to receive more rainfall by ~10% compared to the reference period, while there is only a marginal change in precipitation in OND (the wet season).



Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

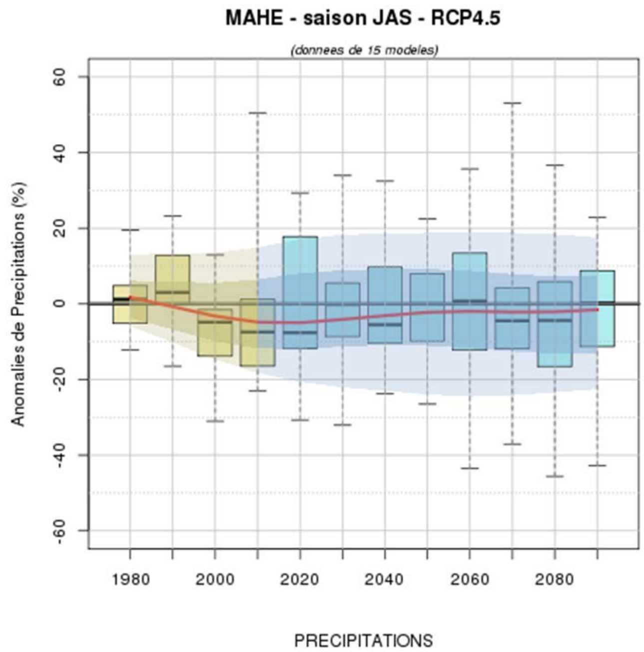
Figure 8. Annual and breakdown of rainfall anomalies for simulated climate 2066 to 2095 compared to 1971 to 2000 climate for RCP4.5.

It is insightful to take a closer look at the time series changes in the mean annual rainfall anomaly for the wet (OND) and dry (JAS) seasons obtained from downscaled climate models. The mean rainfall anomalies for OND and JAS are shown in **Figure 9** and **Figure 10**, respectively, for the period covering 1980 and 2100. The results in **Figure 9** show that there is no clear evidence for any medium-to-long term changes in the mean rainfall anomalies in the wet season. Using the variations observed between the downscaled GCMs as a guide for variability in precipitation, the downscaled modeling suggests lower extreme precipitation events in the wet season compared to those reported in the SNC.



Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

Figure 9. Mean OND rainfall anomalies for RCP4.5: 1980 – 2100.



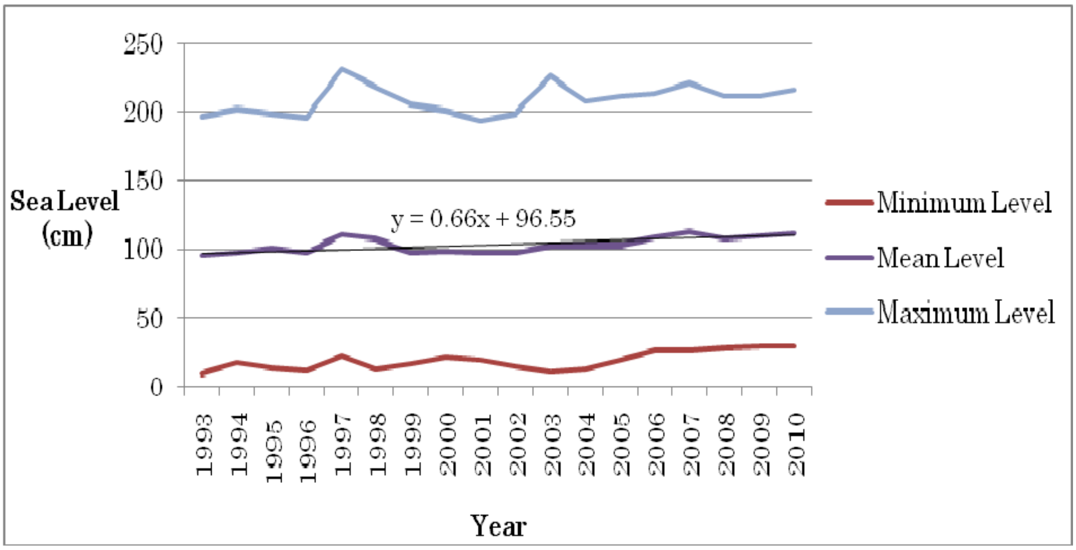
Source: Seychelles Meteorological Authority and Météo France La Reunion, 2016

Figure 10. Mean JAS rainfall anomalies for RCP4.5: 1980 – 2100.

Despite the large variances between the downscaled GCMs, there appears to be a clearer trend of decreasing precipitation in the JAS dry season (**Figure 10**). However, the rainfall anomalies are less than 10%, again revealing a less pronounced drier pattern during the dry season as projected in the SNC. Further, the rainfall anomalies appear to become less pronounced after 2050. Using the variations between the downscaled GCMs as a proxy for variability in precipitation, **Figure 10** shows that precipitation anomalies are expected to be less than 20% during extremes in low rainfall events.

Sea level rise (SLR)

The SNC (Government of Seychelles, 2011b) reported that local SLR of 1.46 mm per year was rather consistent with the global average SLR of an average rate of +1.8 mm (1.3 to 2.3 mm) per year over the 1961 to 2003 period. New analysis (JICA, 2013) has shown that the current mean SLR using data measured at Pointe Larue was 6.6 mm per year (**Figure 11**). A similarly higher SLR has recently been reported for Mauritius and Rodrigues. Whereas previous data showed an increase of 1.69 mm per year (Ragoonaden, 2006), analysis of data measured between 2003 and 2011 has shown SLR increasing at 5.6 mm per year (Ragoonaden et al., 2015).



Source: JICA, 2013

Figure 11. Yearly change in sea level at Pointe Larue, 1993 - 2010.

Wave climate

The energy dissipated when waves reach the shoreline can affect coastal infrastructures, threaten lives and cause coastal erosion. In the Seychelles, offshore wind-wave is mainly dominated by two-directional monsoons (north western monsoon and south eastern monsoon) that give rise to reversal of wind/wave directions during different seasons. Therefore, the wave climate would not be altered to a significant extent unless the patterns of the monsoons change. There is scant information concerning projections of future wave conditions in the Seychelles taking climate change into account. Although there is a wide variation in the results of global climate models studies, there is a tendency toward decreasing frequency of tropical cyclones, but increasing intensity compared to events at the end of the 20th and the 21st century (JICA, 2013). A technique for downscaling tropical cyclone climatology for the Indian Ocean from global analyses concludes similar results, namely an overall tendency

toward decreasing frequency of tropical cyclones and a general increase in storm intensity (INGC, 2009).
Even if offshore wave conditions did not change, greater wave energy would reach the coastal zones of Seychelles because of lower energy loss in deepened sea beds due to sea level rise. The impacts will be more severe coastal erosion and higher wave run-up than those currently occurring.

Sector vulnerabilities

Coastal zones

It is clear from the previous discussions that the impacts of climate change on coastal livelihoods as a result of sea level rise, storm and tidal surges, and coastal flooding will have serious consequences for livelihood on Seychelles. More than 90% of the population and development are concentrated on the coastal plateau of the main granitic islands, which are no more than two km wide. The mean elevation of the coastal plateau of the granitic islands is 2-10 m (Government of Seychelles, 2011b, pg.195).

SLR is expected to affect Seychelles in the following ways (Government of Seychelles, 2011b):

- Destroy properties and infrastructure located on the coastal plains and reclaimed land;
- Inundate agricultural areas, wetlands and the lowlands;
- Cause several low-lying islands, especially the sand cays to disappear;
- Erode the shorelines and beaches;
- Enhance coastal flooding, especially during severe rainstorms and high tides;
- Increase salinity of mangrove swamps and raise groundwater level thus affecting plant growth;
- Threaten groundwater aquifers and coral island fresh water lens;
- Alter tidal ranges in the rivers and bays;
- Alter sediment deposition patterns;
- Affect the coastal and the marine ecosystems

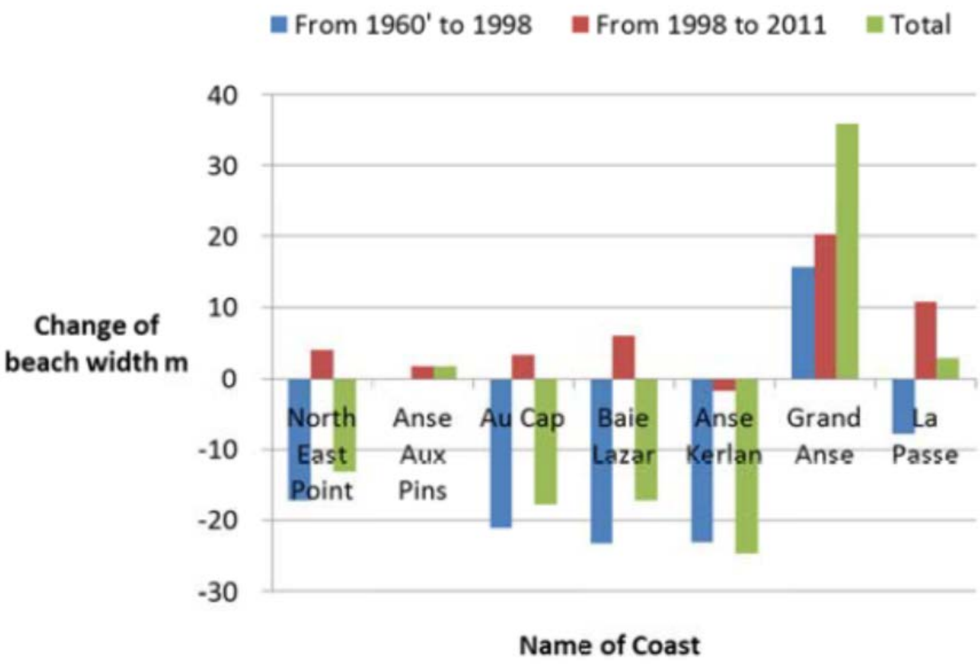
The vulnerability of the coastal zones to *storm surges* and *flooding* due to heavy precipitation were discussed in section 1.2 above (**Figure 2**).Before turning our attention to coastal erosion, it is worth to highlight the gravity of exposure to these hazards through an example. In the year 2100, if 1.4 m of high tide (return period: 25 yrs)[9] is compounded with a SLR of 0.6 m and rivers overflowing by 0,5 m due to heavy precipitation, buildings and roads below 2.5 m (above the present mean sea level) are expected to be inundated (JICA, 2013, pg.2-77). Using present geospatial information this exposure translates into inundation of 2,017 buildings (14%) in Mahé, 1,601 buildings (63%) in Praslin and 321 buildings (48%) in La Digue. The damage will include a total of 11 hospitals, 15 schools, 21 restaurants and 69 hotels/guesthouses. Further, 67 km (42%) of roads in Mahé**,** 43 km of roads in Praslin and 7km of roads in La Digue are expected to be inundated. These include 33 km (42%) of coastal main roads in Mahé, 20 km (72%) in Praslin and 3 km (27%) in La Digue (JICA, 2013, pg.2-78).

Coastal erosion or changes to the profile of the coastline in Seychelles have been attributed to natural and man-made phenomena (Shah, 1994). The man-induced changes have been the result of sand extraction, destruction of protective coral reefs, removal of coastal vegetation, building on sand dunes,

[9] The probable extreme high tide level (cm: above M.S.L) = 11.921 x ln (yrs.: return period) + 105.73 (Source: JICA, 2013, pg. 2-74).

and the construction of sea groynes, breakwaters and piers. **Figure 12** shows the change in the profile of selected beaches on Mahé (North East Point, Anse aux Pins, Au Cap, Baie Lazar), Praslin (Anse Kerlan and Grand Anse) and La Digue (La Passe) using a combination of old maps, aerial photographs, GIS data, and Google Earth (JICA, 2013).

Although it is difficult to ascertain the definitive causes for the dramatic changes in beach width between 1960 and 1998, it is suspected to have been caused by sand mining. The erosion at Anse Kerlan corresponds to the accretion of Grand Anse, thereby excluding the possibility of sand mining as being the proximate cause of beach loss at Anse Kerlan.



Source: JICA, 2013

Figure 12. Change in width of selected beaches.

On the three islands of Mahé, Praslin and La Digue, coastal roads, hotels and residents on the narrow coastal plain are affected by coastal erosion. The causes of erosion are thought to be as follows (JICA, 2013):

- The coastline tends to shift because of the seasonal variation of wave direction caused by the north-west monsoon and the south-east trade winds;
- Coastal structures such as revetments of roads, groynes and breakwaters affect sediment movement and cause erosion and accretion around them;
- Coral sand was lost in past sand mining activities and was also transported offshore through channels through the reef.

Based on tidal, wave and rainfall conditions (present and future), best practice planning and design guidelines contextualised for Seychelles and availability of construction materials locally, the JICA study proposed a set of interventions in priority coastal locations. The technologies that were considered and prioritised using multi-criteria analysis (MCA) are summarised in **Table 2** in descending order of priority (JICA, 2013).

Table 2. Prioritised technologies for adapting to floods and coastal erosion.

Approach	Technology components for coastal erosion	Technology components for flood management

Protect	Nourishment; groyne; detached breakwater; coastal revetment	Drainage improvement; retaining pond; river improvement; ring levee; water gate; pump system
Accomodate	Regulation; EIA; risk map; improvement to houses; awareness; emergency operation; early warning	
Retreat	Setback/zoning; relocation	

Source: JICA, 2013

The priority locations for implementing coastal flooding and erosion countermeasures are given in Table 3. The cost of the structural measures proposed in **Table 3** for addressing coastal erosion has been estimated at SR 28.15 million,[10] and the total cost to 2050 for addressing the long-term remediation of coastal erosion at the priority sites estimated at SR 740 million (JICA, 2013, pg.4-19).

Table 3. Coastal erosion and flooding remedial measures for priority locations.

Priority location	Interventions/Suggestions
Coastal erosion	
North East Point	Sand or gravel nourishment is selected to compensate the loss of sand and to make beach usable.
Baie Lazare	Maintenance of the beach by sand nourishment is better than the direct protection by revetment because the latter causes loss of sand from the beach. The prevention of sand loss at the flooding by submerged reef in front of the channel is not feasible because of its cost. The traffic control at high tide is not reliable and other measures are necessary for future sea level rise.
Anse Kerlan	Since the beach is important for tourism, sand nourishment and groyne construction are appropriate for recovering the beach and for decreasing longshore transport. Revetment may cause loss of beach sand.
La Passe	To decrease accumulation of sediment in the sheltered area, a groyne with sand by passing from anchorage to eroded beach was proposed. The rearrangement of the breakwater and jetty is one of the alternatives. The arrangement of the groyne was considered for future development based on the existing proposed plan. A detailed study is required.
Coastal flooding	
Victoria Town	Short term plan: Drainage improvement of 8 drainage channels totaling 1.3 km with 40% capacity increase. Those are located at Olivier Maradan (88m), Market Street (108 m), Huteau Lane (179 m), Palm Street (121 m), Benezet Street (125 m), State House Avenue (96 m), Independence Avenue (223 m), and Francis Rachel (321 m). Medium-term plan: Improvements of river - 1,080 m of bed excavation, widening of 340 m in length, wall construction of 780 m in length, and elevating dike of 28 m in length. The five target rivers are: English River, River Moosa, River Maintry, River St. Louis, and River La Poudriere.
Pointe Larue	Short term plan: Drainage improvements by the culvert (30 m) under the road, extension of drainage channel (40 m) to wetland, and widening of existing channels. Medium-term plan: Enlargement of the existing culvert of 8 m long.
Anse aux Pins	Short term plan: Construction of a new drainage channel of 120 m long to the sea at Chetty Flat. Medium-term plan: Improvement of rivers near the mouth. One is river bed excavation of 300 m, and the other is widening of the river over 200 m with construction of new box culvert.
Au Cap	Short term plan: Improvement of drainages. Medium-term plan: Improvement of rivers near the mouth by widening over 620 m, and construction of two bridges with widening of river mouth (230 m).

[10] US$ 1 = SR 13.5.

Anse Royale	Short term plan: Construction of a 120 m long drainage ditch. Medium-term plan: Improvement of two rivers near the mouth by widening of the rivers (170 m), river bed excavation (1400 m), and construction of a bridge with widening of river mouth (130 m).

Source: JICA, 2013

Water sector

Because of its small size and particular geological, topographical and climatic conditions, Seychelles face severe constraints in terms of both the quality and quantity of freshwater. Even when rainfall is abundant, access to clean water has been restricted by the lack of adequate storage facilities and effective delivery systems (Government of Seychelles, 2011b). Water Evaluation And Planning (WEAP)[11] system has been used to study the climate, socio-economic and technological change impacts on the water resources in Seychelles using scenario analyses between 2006 and 2030 (see **Table 4**).

Table 4. Definition of scenarios used in WEAP modeling.

Scenarios	Definition
Reference	The **likely evolution of the system without intervention**. The 'Reference' scenario is constructed with the key assumptions that the 1990-2000 population growth rate of 1.2% continues up to the year 2030, with current baseline socio-economic and technological conditions. The population in that case would increase from 73,900 to 98,395 individuals by the year 2030.
'what-if' scenarios	The following parameters are modelled : • Moderate to high (1.8%) population growth; • Climate variability; • Economic development in the tourism, fisheries, agriculture and industrial sectors; • Demand management scenarios (i.e. improved technological devices at the residential and agricultural demand sites);
Water Supply Management scenario	• Increasing storage capacity by 30% at Le Niol in 2010 and Cascade in 2012 • Overall gradual reduction in water loss during transmission decreases from 40 % to 10% by the year 2030 • Desalination activities are considered active only during the dry season with a supply flow of 0.1175 cubic metres per second from April to October

Source: Government of Seychelles, 2011b

The results of the WEAP analysis are shown in **Table 5**.

[11] http://www.weap21.org/ - accessed 15 February 2017.

Table 5. Scenario analysis of unmet water demands using WEAP modeling (million litres).

Scenario	Year				
	2010	Water Demands (million litres)	2020	2025	2030
High Population Growth	1487.29	1717.55	2047.81	2549.68	3173.55
Economic Development	1582.95	2001.51	2677.15	3549.19	4621.03
Climate Fluctuation	1808.88	1577.67	1426.49	1958.72	1770.41
Reference	1429.77	1577.67	1738.30	1958.72	2217.65
High Population Growth-Reference	57.51	139.88	309.51	590.95	955.90
Economic Development-Reference	153.18	423.83	938.853	1590.47	2403.38
Sum of Water Stressors (WS)	4879.10	5296.70	6151.50	8057.60	9565.00
Sum of Water Stressors (WS)-Ref	3449.40	3719.10	4413.20	6098.90	7347.40

Source: Government of Seychelles, 2011b

Therefore, the economic development sector contributes to a larger unmet demand compared to that of the high population scenario. If the climate fluctuation is factored into the analysis, the unmet demands are 1808.9, 1577.7, 1426.5, 1958.7 and 1770.4 million litres, respectively, for the years 2010, 2015, 2020, 2025 and 2030. The performances in some years are better or worse depending on the climate. During the relatively wet years, the unmet demand is lower while it is higher in the projected dry years.

The WEAP results have shown that the sum of the combined water stressor (WS) defined here as the worse-case scenario policy ranging from the effect of likely climate fluctuations, high population growth and sector economic development were characterised by 4879, 5297, 6151, 8058 and 9565 million litres of unmet demand for the years 2010, 2015, 2020, 2025 and 2030, respectively. These figures have highlighted the drastic increase in the deficit of water which fundamentally poses a serious risk to the sustainable development of the country.

The technological interventions underlying the adaptation scenarios listed in **Table 4** have positive effects on attenuating the water deficits. If the Seychelles were to face worse-case scenario conditions (**Table 5**) (i.e. socio-economic development and climate fluctuation), then the net demand (i.e. improved demand-side technological devices) and supply (i.e. desalination, improved water transmission, improved water storage) management scenario strategies would alleviate the large water deficit. The combined strategies has the potential to contribute to water surplus of 16406, 19906, 27342, and 33059 million litres for the years 2015, 2020, 2025 and 2030 respectively (Government of Seychelles, 2011b).

Agriculture sector

The bulk of land based food crop production in SIDS are still done through agricultural practices which are being carried out in open soil systems or open field cultivation systems. The rain-fed agriculture is directly exposed to climate change and variability in terms of extreme weather events such as droughts and floods, high temperatures leading to plant stress and low humidity retention in soils. Overall agricultural output is a product of soil attributes (physical, chemical and biological), prevailing climatic conditions (medium-to-long term) and agricultural management practices (Moustache, 2015). As discussed in section 1.2, SIDS are confronted with a number of non-climatic vulnerabilities. After 2008, following the world economic downturn, the implementation of austere national economic reform programme led to an open market policy that caused the collapse of the national livestock sub-sector (Moustache, 2015). The crops sub-sector suffered from the subsequent lack of manure inputs. Local food output is now 100% table eggs, 50% vegetables and fruits, 7% pork and 10% broiler poultry (quoted in Moustache, 2015), with remaining demand met through importation.

There is scant information on the quantitative impacts of climate change and variability on agricultural output. This, together with the detrimental impacts of the 2004 tsunami that was followed by excessive rain and strong winds prompted two studies to be carried out under the SNC, namely: (1) establishing an insurance mechanism to protect crop and livestock producers and fishermen against natural disasters; and (2) understanding the seasonal response of lettuce to weather stresses and the implications of climate change on crops in the Seychelles. The first study established the vulnerability (on a 4 point scale: least, slightly, moderate, high) of crops to rain, drought and wind (Government of Seychelles, 2011b). Because of the short temporal scale of the second study, the following recommendations were made (Government of Seychelles, 2011b):

- More experiments and detailed modelling are required to confirm the optimum effects and the two critical threshold values of maximum temperature during the two respective seasons;
- Detailed modelling is required to understand the effects of narrowing down the gap between the daylight maximum temperature and the night time minimum temperature;
- Future experiments should be repeated each year at the same time to study the year to year performances;
- Carry out a variety of crop experiments to assess crop vulnerability;
- Improve crop data management and quality checks at farm level;
- Assess the challenges and impacts of climate-crop performance using an actor-oriented analysis approach at the multi-level and scales.

Fisheries sector

The fisheries sector is a pillar of the Seychelles economy, and it is vulnerable to the impacts of climate variability manifested in El Niño Southern Oscillation (ENSO) events. The 1997-98 warm event, which coincided with one of the strongest ENSO events in the last century, caused dramatic temperature and wind stress anomalies in the equatorial Indian Ocean. This event changed the oceanographic distribution of the purse seine tuna fishery drastically resulting in the fishing grounds of the Western Indian Ocean (WIO) basin being deserted in favour of the Eastern basin, as far as 100°E. Purse seine fleets based in the WIO had never reached that far East prior to this ENSO event. Consequently, landings and vessel activity in Port Victoria decreased substantially as the fleets operated from Asian ports (notably Phuket, Thailand), resulting in socio-economic impacts for the fishing industry and related activities in the Seychelles (Payet, 2005). However, the 1997-98 ENSO event is considered to be an outlier as other warming events (even the relatively strong ones of 1994 and 2006-2007) did not produce any observable changes on tuna catches and the economy (Government of Seychelles, 2011b). The impact of climate variability on the fisheries sector is made difficult by two factors: (1) predicting ENSO anomalies remain uncertain,[12] making adaptation in a fisheries sector reliant on pelagic fishes difficult; and (2) it is difficult to distinguish the impacts of climate oscillations from other effects (e.g. the introduction of purse-seiners of bigger size, increasingly assisted in fishing by supply vessels, the deployment of fish aggregating devices, and sophisticated electronic means of fish detection, such as bird radars, sonar and echo-sounders) acting

[12] https://www.climate.gov/news-features/blogs/enso/predicting-el-ni%C3%B1o-then-and-now – accessed 15 September 2016.

on the Seychelles tuna-related industries because no single model has explicitly attempted to account for all determining factors simultaneously.

Health sector

The spread of the *Aedes albopictus* (the mosquito vector for chikungunya, dengue and yellow fever) was measured on Mahé during the implementation of the SNC, and an attempt was made to correlate the incidence of chikungunya with climate parameters (temperature and rainfall). It appeared plausible that an increase in rainfall and temperature could have explained the positive correlation between the number of chikungunya cases and rainfall patterns/temperature at the onset of chikungunya in 2005. However, it would be right to also suggest that more people contracted the disease as transmission rates increased in that period as the number of infected persons increased. However, the number of chikungunya cases was only positively correlated with the amount of rainfall during the start of the outbreak. This was followed by a negative relationship. Hence, there were other factors (e.g. intervention measures like cleanups and spraying activities) that played a role in influencing the number of chikungunya cases other than rainfall and temperature.

The relationship between the incidence of vector-borne diseases (e.g. chikungunya) and climate change is still not clear. The SNC mentioned that in order to develop policies to mitigate and adapt to climate change-related health impacts, it is important to continuously understand and seek evidence of the ways climate change will affect the patterns of human health (Government of Seychelles, 2011b, pg.316).

1.4.2 Process and results of sector selection

The process for prioritising sectors for the TNA project has relied on the sectoral vulnerability assessments discussed in the previous section. The development priorities are also based on the vulnerability assessments. The sectoral priorities are clearly written in the latest documents such as the Seychelles Strategic Plan 2015 – 2040 (Government of Seychelles, 2015b) and the Seychelles INDC (Government of Seychelles, 2015a) related to addressing the impacts of climate change in Seychelles. It is pointed out that the development of these documents has made use of inclusive, broad-based multi-stakeholder dialogues.

The Seychelles Strategic Plan 2015 - 2040 (Government of Seychelles, 2015b) proposes an integrated strategy for adapting to the impacts of climate change that provides much insight into the national adaptation priorities. The Seychelles Strategy Plan integrates the objectives and strategies espoused in the NCCS and the NDRMP discussed in section 1.2. In order to respond and improve resilience to climate change, the Seychelles Strategic Plan proposes the following components that are related to climate change adaptation:

- Put in place measures to adapt, build resilience and minimise vulnerability to climate change.
- Develop technical data and analytical models for predicting impacts of climate change and monitor vulnerable priority areas.
- Establish a risk based national strategy for the management of development in landslide and flood risk zones that can be used as a tool to help identify those locations which are suitable for (different types of) development.
- Promote integrated water resource management.
- Encourage distributed, localised networks of utilities, including water and energy storage, to improve resilience of provision.

The measures to achieve the above components are summarised in **Table 6**.

Table 6. Measures proposed in the Seychelles Strategic Plan related to climate change adaptation.

Policy CC1 Mitigate and Adapt to Climate Change and Disaster Risk Reduction Adaptation should be achieved through: • Adopting a risk-based approach to flood risk and coastal management. • Locating strategic development where there is greatest protection from impacts such as flooding, landslides, coastal erosion and storms, and ensuring the protection of existing infrastructure, including roads. • Ensuring new and existing building stock is more resilient to climate change impacts. • Developing a long term drainage strategy to implement sustainable urban drainage systems across the Seychelles. • Incorporating high standards of water efficiency in new and existing building stock. • Developing sustainable new water resources. • Ensuring that opportunities and options for sustainable flood management and protection of habitats and species are actively promoted.
Policy CC3 Manage Flood Risk • Applications for development will be required to demonstrate that they will not result in an increase in flood risk within the application site and elsewhere. Where possible, new development should be avoided in areas of high susceptibility to flood risk. Where vulnerable development is proposed in areas susceptible to flooding, it should be demonstrated that sufficient mitigation measures have been put in place to minimise exposure to flood risk. • All developments in flood risk areas and of a pre-defined size should provide a flood risk assessment to demonstrate that flood risk from all sources of flooding will be managed.
Policy CC4 Improve Storm Water Drainage • New development should comply with guidance set out in the Storm Water Drainage Design Guidelines. • Storm water drainage is in place on many of the highways in Seychelles. Despite this, localised surface water flooding still occurs, which indicates that there remains a requirement for localised improvements, greater attenuation and an increased number of outfalls to the sea.
Policy CC5 Protect Critical Infrastructure from Natural Hazards • Critical infrastructure and/or emergency services will be located outside areas of high susceptibility to natural hazards unless it can be demonstrated that lower risk areas are not feasible or viable, and mitigation or protection measures are provided. • The localised protection and/or relocation of critical infrastructure and emergency services will be supported subject to other policy considerations of the Plan. • Infrastructure considered to be of critical national significance are likely to include: ➢ Power stations and any power network over 25kV ➢ Trunk telecoms infrastructure ➢ Television and mobile phone masts ➢ Primary roads ➢ Reservoirs and high pressure water mains ➢ Oil terminals and associated pipeline ➢ Airports and offsite navigation aids • A resilience strategy should be developed, covering the following key elements: ➢ Assessment of procedures: education, notification, warning etc ➢ Mapping and identification: map and identify critical infrastructure at risk; audit critical systems

➢ Protection/mitigation: provide the necessary protection to those facilities identified to be at risk ➢ Relocation: consider relocation of facilities at risk, should protection measures not be feasible ➢ Adaptation: use of new technologies to reduce risks ➢ Modelling and testing: model and test the resilience of Victoria to various risks and continue to monitor vulnerability of key infrastructure
Policy CC7 Establish a Water Hierarchy The Government of Seychelles will apply the following water hierarchy: ➢ Mean: reduce demand through education and measures such as water efficient fittings and fixtures. ➢ Lean: reduce losses through encouraging upgrading of pipe network and local generation. All new developments will be expected to provide facilities for individual rainwater harvesting and water storage. ➢ Green: minimise environmental impact of water generation and avoid overuse of desalination. Explore and identify potential sources of groundwater and opportunities for groundwater recharge, whilst avoiding over-abstraction of groundwater.

Source: Government of Seychelles, 2015b

In summary, the impacts of climate change as a result of sea level rise, storm and tidal surges and coastal flooding will have serious consequences, as will changes in long term rainfall patterns and temperature changes. Based on the developmental priorities and vulnerability assessments discussed above, and combined with resources constraints (financial and time), the two priority adaptation sectors retained for the TNA process are:

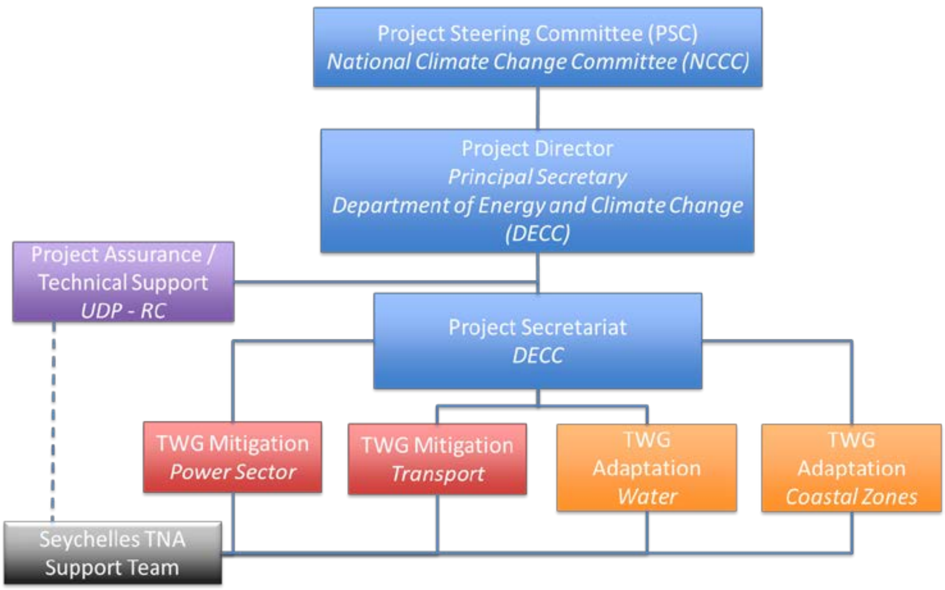
1. Coastal zones, and
2. Water.

Chapter 2 Institutional arrangement for the TNA and the stakeholder involvement

The institutional arrangement has been set up taking in account two considerations, namely: (1) the guidance note on the institutional arrangement proposed for the TNA project (Dhar, 2014), and (2) the existing institutional structures already in place in Seychelles for managing and coordinating CC activities. The latter is particularly important given the fact that Seychelles suffers from limited human resources due to its small population base. This constraint means that the multiplicity of institutions has to be minimised. The small pool of human resources also imposes constraints on the stakeholder engagement process that can be carried out in terms of both the type and the number of working sessions. In contrast, smallness bestows the advantage of close proximity between project stakeholders and the relative ease of bilateral interactions.

2.1 National TNA team

Figure 13 shows the institutional arrangement that has been set up to manage the TNA project in Seychelles. The essential elements of the institutional arrangement include a Project Steering Committee (PSC), Project Director (or TNA Coordinator), Project Secretariat, Sectoral Technology Working Groups (TWG), Seychelles TNA Support Team (i.e. National Consultants/Experts) and Project Assurance. The roles and responsibilities of these different elements of the institutional structure are discussed in the next section.



Source: TNA project

Figure 13. Institutional arrangement for the TNA project in Seychelles.

The PSC provides political support for the outcomes of the TNA project. In particular, it provides guidance for acceptance and final recommendations for consideration and/or approval at Ministry and Governmental level to the TNA outcome. The PSC is comprised of high-level representatives from the institutions responsible for policy making related to the selected technologies with regard to both adaptation and mitigation. The National Climate Change Committee (NCCC) serves as the PSC. The TNA project serves as an opportunity to revamp the NCCC so that it becomes the national institutional structure providing the cross-sectoral coordination of all CC-related initiatives in

Seychelles. Ultimately, the NCCC will provide oversight and political support for the mainstreaming of CC at all levels for the efficient and effective implementation, monitoring and evaluation of the various climate change processes including the INDC.

The PSC is chaired by the Principal Secretary of the Department of Energy and Climate Change (DECC), Ministry of Environment, Energy and Climate Change (MEECC), or representative (Head of the Seychelles National Meteorological Services). The Principal Secretary is also the Project Director, a position equivalent to the National TNA Coordinator, who has the responsibility of ensuring the smooth implementation of the TNA project on a day-to-day basis. The Project Director is also the National Climate Change Focal Point.

A Secretariat for implementing the TNA project is provided by the DECC. The main role of the Secretariat is to provide administrative support for coordinating the TNA project stakeholders who constitute the sectoral Technology Working Groups (TWGs), and to facilitate the working sessions of the TWGs. The TWGs are the stakeholder platforms through which the project is implemented. There are four TWGs each representing one priority sector in the TNA project as discussed in Section 1.4 above for adaptation (i.e. coastal zones and water) and as discussed in Section 1.3 of the TNA Report for Mitigation (i.e. energy industries and transport). The members of the TWGs for the adaptation priority sectors are summarised in **Annex II**.

The Seychelles TNA Support Team is comprised of one international consultant and three national consultants. The responsibility of the international consultant is to provide technical assistance in implementing the TNA project, and to provide capacity building of project stakeholders and national consultants regarding the TNA process, methodologies and tools. The international consultant acting as Team Leader of the TNA Support Team also has the responsibility to ensure the first level of quality assurance for project deliveries. The main task of the national consultants is to provide technical support to the TWGs with the support of the Team Leader. Each adaptation priority sector is assigned a CC adaptation expert (and there is one national consultant supporting both mitigation priority sectors). The TNA Support Team also liaises with the UNEP DTU Partnership (UDP) and the Regional Centre (Energy Research Centre, University of Cape Town) to ensure that the TNA project and its deliverables are completed to the highest quality and standard. Finally, the TNA Support Team is tasked to represent the Seychelles in TNA Regional Capacity Building and knowledge sharing workshops.

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

The members of the TNA Support Team were closely involved in the process of formulating the Seychelles INDC that took place between May and October 2015. The development of the Seychelles INDC necessitated multi-stakeholder engagements across different sectors. Given the back-to-back implementation of the INDC and the TNA project, the latter has benefitted from the prior multi-stakeholder process.

A combination of bilateral and technical working group meetings was used to accomplish the process of technology identification and prioritisation. The summary of meetings held, including institutions and persons participating in the TNA process, is given in **Annex II**.

Chapter 3 Technology prioritisation for the Coastal Zone Sector

3.1 Introduction

This chapter focuses on measures to protect natural ecosystems and critical infrastructure in the coastal zone. The natural coastal ecosystems in Seychelles include mainly coastal freshwater marshes, mangrove forests, the dunes and beaches found around the islands of Seychelles, as well as the coral reefs which fringe the main islands and provide a natural protective structure for the coast. Coastal ecosystems all provide important habitat for biodiversity and the reefs provide a source of fish for the human population. Coastal ecosystems also function as natural structures protecting the coast from erosion against SLR, storm surges and severe wave action during storms. Fresh water marshes and mangroves provide absorptive capacity to help reduce flooding during times of heavy rainfall. In Seychelles, natural coastal ecosystems, particularly beaches and coral reefs, are important for tourism as well as for leisure activities for the local population.

Because of Seychelles' mountainous topography, most of its critical infrastructure is found in the narrow coastal plateau surrounding the main populated islands of Mahé, Praslin and La Digue. This includes main roads, electricity and water supply infrastructure, ports and fisheries infrastructure, and many buildings. The mean elevation of the coastal plateau around the granitic islands is 2-10 m (Mendez et al., 2013). Most of the critical infrastructure like roads, power stations and food storage are in the range of 2-4 m above sea level and most vulnerable to flooding.

3.2 Key Climate Change Vulnerabilities in the Coastal Zone Sector

As mentioned earlier, the coastal zone of Seychelles is vulnerable to SLR, storm surges and strong wave action during storms. In addition, during times of heavy rainfall, the coastal zone is vulnerable to flooding, which is exacerbated when heavy rainfall coincides with high tides and heavy seas (See section 1.3 and 1.4.1).

Over the long term, SLR is the biggest concern. As discussed in section 1.4.1, local SLR of about 6.6 mm per year has been observed.[13] This about 3 times higher increase that what has been previously reported. According the SMA (2016), by 2100, under the most modest predictions, we can expect SLR of about 300 mm, and closer to 1 m under worst case scenarios. A study undertaken by a Cuban scientific team in collaboration with the Government of Seychelles in 2013 mapped out coastal areas that were most vulnerable to damage by sea level rise under the different scenarios, including scenarios involving sea level rise coupled with a storm wave event (Mendez *et al*., 2013). An increase in cyclonic activity affecting the main populated granitic islands of the Seychelles is unlikely but extreme wave swells from cyclones in the region do remain a possibility and indeed such events have occurred in the recent past, causing damage to beaches and roads along the coast (JICA, 2013).

Although SLR may be the biggest long term threat to coastal infrastructure, Seychelles has already suffered damages from intense rainfall and coastal flooding, which may be related to climate change in addition to other factors. The discussions in section 1.4.1 suggest that rainfall patterns are expected to increase over the next 80 years, during the seasons from October to June. The dry season occurs from July to September but the results from models are not consistent, with scenarios ranging from increased rainfall, the same amount, and decreased rainfall. What the data does not yet show is if and how the pattern of rainfall might change, in terms of amount falling in one short period, and more falling in some areas than others.

The study conducted over a three year period by JICA (2013) has identified some of the key vulnerable areas to coastal flooding from severe hydro meteorological events on the main populated islands, based on historic rainfall patterns and existing drainage systems. These areas are as follows: Victoria town, Pointe Larue, Anse Aux Pins, Au Cap and Anse royale, Baie Lazare, Anse Boileau,

[13] Global SLR averages about 3.4mm per annum according to NASA (2016),

North of Mahé, South-west Praslin, and West La Digue (see sections 1.3 and 1.4.1 for more details). Further as summarised in **Table 3**, the JICA report also highlighted the following coastal areas that were highest priority for action to control or reduce erosion: North east point, Anse Aux Pins, Au Cap Anse Royale, Takamaka, Baie Lazare, Anse la Mouche, Anse Boileau, Beau Vallon, Anse Kerlan & Anse Lazio - Praslin, and La Passe La Digue.

Mendez *et al.*, (2013) also identified the following areas on the main populated islands (Mahé, Praslin and La Digue) as most vulnerable to coastal flooding as a result of extreme hydro meteorological events and to sea level rise, many of which overlap with the JICA findings above:

- *Very high vulnerability*: low-lying areas of Grand Anse, Praslin, Baie Ste. Anne, Praslin, La Digue and Beau Vallon;
- *High vulnerability*: low lying areas of Port Glaud, Glacis, Bel Ombre, Roche Caiman, Au Cap, Baie Lazare, Anse Etoile, Mont Fleuri, Grand Anse Mahé, Anse aux Pins and Plaisance; and
- Over the long term, with sea level rise projections of up to 1m by 2100, the vulnerability of the port area of Victoria was highlighted.

Given the concentration of economic activity taking place in the low-lying areas along the coast, it is critical that Seychelles consider implementing proactive measures against SLR, storm surges and coastal flooding. As discussed in section 1.4.1 (please see **Table 2** and **Table 3**), the main focus will be on technologies to adapt to coastal erosion due to SLR and increased wave action. Nevertheless, some technologies for adapting to coastal flooding have also been included for consideration.

3.3 Decision context

For Seychelles, protecting the coast from the impacts of climate change is considered high priority and an integral component of several key national plans and policies as already discussed in section 1.2 and summarised in **Annex I**. Despite this, the day-to-day reality of dealing with coastal erosion and flooding instances is more of a reactive and ad-hoc approach, rather than being proactive and systemic, planning ahead for the long term. Existing development plans refer to climate change but the actual developments going ahead are at times inconsistent with a forward-thinking climate proofing approach to development in the coastal areas. The TNA provides an opportunity for stakeholders to reflect on future scenarios and how best the country should invest its limited resources to protect coastal infrastructure from SLR and coastal flooding.

The policies, strategies and action plans framing adaptation to climate change were discussed in section 1.2. For conciseness, they are not repeated here. The focus is instead on projects that are complementary to the TNA project for two main reasons, namely: (1) to avoid duplication; and (2) to seek collaborative synergies with the objective to deliver the most productive use of the limited resources available under the TNA project. These projects are listed in **Table 7**.

Table 7. Summary of ongoing climate change adaptation projects in Seychelles.

Project Title	Project summary
EBA Watershed project – "Ecosystem Based Adaptation to Climate Change in Seychelles"	This US$ 6 million project funded by the Adaptation Fund and managed by the UNDP aims to help Seychelles adapt to climate change through an EBA approach addressing water scarcity and flooding. The project focuses on several different watersheds and is considering the possibility of funding a breakwater at North East point to help control beach erosion.
UNEP Coastal EBA project – "Building Capacity for Coastal Ecosystem-Based Adaptation in SIDS"	This regional project is focused on helping SIDS increase their capacity to adapt to climate change through EBA approaches. The project is being implemented by the MEECC and is focused on providing capacity to SNPA on the following: (1) coral reef restoration; (2) beach profiling; (3) Mapping; and (4) economic valuation of coral reefs and beaches. The project is nearing completion, and complements a number of other ones, including the coral reef restoration done by Nature Seychelles at Anse Kerlan and near Cousin island.

Coastal Erosion at Anse Kerlan, Praslin	The project, initiated by a community based organization (The Anse Kerlan Avantgarde Committee) with funding from the GEF small grants program, is a renewed attempt to control erosion at Anse Kerlan. Rock pilings have been placed along one stretch of the beach to create a seawall, and the Avantgarde Committee has reported securing funding to complete bathymetric and hydrological studies to better understand the causes of erosion in that area.
EBA China/UNEP/GEF project "Global: Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries"	The project is being financed (US$ 828,941) by the GEF Special Climate Change Fund (SCCF) and China's South-South Cooperation Programme on Climate Change (SSCP). It is a joint initiative co-managed by the China National Development and Reform Commission (NDRC) and United Nations Environment Programme (UNEP). This demonstration project, implemented by MEECC, is focused on restoration of coastal wetlands, particularly mangroves. Ten key sites on Mahé, Praslin and Curieuse have been chosen for restoration works which include replanting as well as improving hydrological flow between fragmented segments of a mangrove forest. Restoration work is now underway, along with community workshops, trainings and awareness activities on the importance of coastal wetlands.
GCCA+ La Digue project	The 1.5 million Euro project is funded by the Global Climate Change Alliance, and is managed by the UNDP Project Coordinating Unit of the MEECC. With its focus on the island of La Digue, the project activities consist of studies and scientific surveys, and construction of drains and bridges on five identified outlets. The objective is to put in place adequate infrastructure to allow the water to flow to the sea and hence prevent flooding upstream.

Source: TNA project

The context also covers the legal and regulatory framework, and guidelines within which decisions are made concerning coastal zone protection. The main legislations are:

Environment Protection Act, EPA (1992)
Under this legislation, coastal zones are mentioned in terms of provisions for the Minister (for environment) to designate a "coastal zone" and what should be included in the coastal zone management plan. The only law pertaining to environmental quality is related to dumping of waste, although there is provision for the Minister to introduce regulations relating to the preservation and conservation of the coastal zone. Regulation 3(1) of the EPA pertains to activities requiring environmental authorisation and several of them are very relevant to development in the coastal zone, such as the construction of harbours, sea defenses including sea walls, and dredging. Regulation 3(2) pertains to protected areas, which include coastal systems such as wetlands, the coastal strip, beaches and lagoons. Whereas the protected areas are defined, the type and level of protection are not stipulated.

Town & Country Planning Act (1972)
This act is under revision, and the revised law is expected to incorporate a 25m setback from the high water mark that the MEECC is proposing. The act also makes provision for construction of buildings, including building codes, which are also currently under review. The new version is intended to take into account issues of water and energy efficiency as well as climate proofing.

State Land & River Reserves Act (1903)
This act makes provision for a setback of 10 m on either side of a river, where any developments or clearing of trees require special permission.

Seychelles National Wetland Conservation and Management Policy (2005)
The stated policy objective is to "Protect and conserve wetlands so that wise and sustainable use of their functions and values, including indirect benefits, are secured now and in the future" (Government of Seychelles, 2005). A list of specific wetlands are classified as either A or B, with those in class A not permitting any developments, while some types of developments are allowed in class B wetlands, subject to an EIA. This wetland policy is, however, not a law and therefore only a

guideline, which has resulted in numerous developments in or adjacent being proposed and approved since the approval of the policy in 2005. The policy is being reviewed under the EBA China project.

3.4 Overview of Existing Technologies in the Coastal Zone Sector

Table 8 provides an overview of the technologies that have been used in Seychelles to protect the coast and coastal infrastructure.

Table 8. Technologies used in Seychelles to protect the coast and coastal infrastructure.

Technology	Description and status
Sea wall - stone	Low seawalls made of stone are common in many areas around the main island of Mahé, where they were constructed during the colonial era to provide a base for roads along the coastal beaches and wetland areas. Some of these seawalls are currently being compromised by wave action. This hard engineering protective measure is no longer in favour and rarely used now.
Sea wall – timber piling	This type of sea wall or dune restoration technology has been tried out in four locations (Cote d'Or, on Praslin, and Anse Boileau, Anse Royale and Anse La Mouche on Mahé) over the last 15 years. All sites used a double row of logs with some geotextile lining in between to retain sand. Where space permitted, this method has been coupled with attempts to replant native coastal vegetation. The success rate of timber piling in Seychelles has been inconsistent.
Sea wall – rock armouring	Most of the recent reclamation work around the islands of Mahé, Praslin and La Digue has been contained with rock armouring using local granite rocks. Rock armouring has proved a successful albeit unsightly method against coastal erosion so far, although in some areas the reclaimed land itself is low lying and vulnerable to SLR and storm surges. Rock armouring has also been used increasingly in recent years as an urgent protective measure against instances of severe and sudden coastal erosion due to a variety of factors besides possible SLR. The rock pilings are considered by many individuals to be an eyesore. However, in some instances the rock armours have successfully resulted in sand accretion over time and become submerged under sand. Where space permitted, this technology has been coupled with replanting of dune vegetation at the top of the rock armouring.
Beach nourishment	Beach nourishment has been attempted in only one location (North East point) so far, using sand dredged offshore of Mahé island. The results are inconclusive, but there is consensus that this technology is too expensive and unsustainable for Seychelles.
Groynes	This technique has been used extensively in the past but not always to good effect. In many cases, small poorly designed groynes designed to protect one area of beach or encourage sand accretion have resulted in beach degradation in adjacent areas. Some groynes have been built to protect ports or mooring areas of some islands and proven effective without deleterious effect on the surrounding coast. Experience shows that groynes can work when well designed, by taking into account currents and allowing for sand movement.
Detached breakwaters	This technology has only been tried out in two locations so far in Seychelles (on La Digue at La Passe and in front of the Ste Anne harbor), both of which were constructed to protect tourism infrastructure. The EBA Watershed project is looking into the possibility of constructing one at North East Point on Mahé to encourage sand accretion (at the same site where beach nourishment was attempted a few years ago). This technique could be combined with coral reef restoration by providing additional structure to raise the height of an existing reef.
Dune restoration	The dunes in Seychelles are generally restricted to a very narrow strip of sand between the high tide water mark and the coastal road. Over the last 20 years there have been several significant projects, mostly on Mahé, to restore the dunes with native vegetation and restrict vehicle access using bollards. At Grand Anse Mahé, a boardwalk was built to provide pedestrian access to the beach via only one route instead of many. In many cases, these restoration projects have involved the participation of communities, wildlife clubs and schools.
Wetland restoration	There has been some work done over the past couple of decades to clean and replant some mangrove areas (particularly in Port Launay and Roche Caiman) and to clean the freshwater marsh at North East Point. When coastal wetland outlets become seasonally

Technology	Description and status
	blocked with sand and/or rubbish and natural debris, the habitual response of the MEECC wetland unit is to dredge the opening to allow the river water to flow out and reduce risk of flooding.
Coral reef restoration	The last ten years have seen several coral reef restoration projects, the most significant being that initiated by the NGO Nature Seychelles in the vicinity of Cousin Island and Praslin. Most of the coral restoration work has focused on propagating coral species resistant to bleaching. This is considered to be a promising technology for coastal protection by many stakeholders.
Coastal mapping	The Department of Risk and Disaster Management (DRDM) has been working in collaboration with other partners to map areas at risk of flooding during heavy rainfall and high tides. The studies conducted by JICA (2013) and by Mendez et al. (2013) provide a good base for flood maps under different rainfall and SLR scenarios.
Flood warning system	DRDM does have a flood warning system in place based on information received from the Seychelles Meteorological Authority (SMA) about predicted rainfall. Information is shared with the public via text message, television and radio. The Met Services set up a digitized system several years ago to collect detailed data for flood warnings but this system proved to be too expensive and was abandoned.
Bathymetry, hydrography and other mapping techniques	The Seychelles coast guard and other stakeholders have undertaken bathymetric studies at various times of different areas of the coast around the islands of Seychelles. However, there is no complete and regularly updated dataset available to guide decision-making about measures to protect the coast, coastal ecosystems, wetlands etc. Light Imaging, Detection and Ranging (LIDAR) has been tried out as well as some other technologies but they remain to be explored in more depth and in a more coordinated manner.
Coastal setbacks	There is currently a planning guideline in place requiring any new builds along sandy coast to be at least 25 m back from the high tide water mark. Construction adjacent to wetlands and river areas is limited to a distance of 10 m on either side.

Source: TNA project

3.5 Adaptation technology options for the coastal zone sector and their main adaptation benefits

The long list of technology options for the coastal zone sector was discussed and agreed by stakeholders. The entries in **Table 9** are not prioritised. Several of the technologies are similar to those discussed in **Table 8,** which have already been tried out to various degrees in Seychelles. Their adaptation benefits are described in **Table 9**.

Table 9. Coastal zone adaptation technology options and their benefits.

Technology option	Climate Change Adaptation Benefits for the Coastal Zone
Mapping	This technology includes a number of hydrological methods like bathymetry, as well as the use of LIDAR (airborne laser scanning) to create maps and monitor seasonal and temporal changes to the coast, currents, wetlands and beach profiles. It also includes flood hazard mapping whereby areas of highest risk of flooding from heavy rains and/or high tides or storm surges are identified. The information provided by mapping technologies is critical to guide decision-making about the most appropriate protective measure against erosion and flooding along vulnerable areas of the coast.
Seawalls and groynes	These are both hard engineering options to protect the coast. A seawall is built parallel to the coast, right along the coastline, at the foot of possible cliffs or dunes. A seawall is usually made of concrete or rocks, it can be sloping, smooth, stepped or curved. It can also be built from steel or wood. All seawalls are designed to withstand severe wave action and storm surge, protecting infrastructure and built constructions further inland. Groynes are built perpendicular to the coast, jutting out into the sea, and are designed to catch and trap part of sediment moving in a surf zone (mainly in a longshore direction), and reduce sediment transported seawards.. The general function of groynes is to accelerate sand accretion, but this works best in areas with weak and moderate waves otherwise they can cause sand to erode downshore.

Technology option	Climate Change Adaptation Benefits for the Coastal Zone
Flood warning system	A flood warning system works in conjunction with flood hazard mapping whereby coastal areas which are at risk of flooding under extreme conditions are identified and monitored. A flood warning system is intended to reduce the impact of coastal flooding, by providing information about areas at risk, and ensuring that the public, local authorities and other key stakeholders are aware of these risks. In situations of heavy rainfall and/or extremely high tides, a flood warning system will ensure that stakeholders are aware of the situation and measures are taken to reduce damage to infrastructure and loss of life.
Detached breakwater	Detached breakwaters are hard engineering measures built in the sea, parallel to the coast to reduce wave energy eroding the coastline. The higher the breakwater, the lower wave energy transmission, but in this case there is a higher aesthetic impact. Detached breakwaters can be designed as single, segmented, emerged or submerged, etc., depending on the shoreline.
Coral reef restoration and augmentation	Coral reef restoration involves natural and artificial measures to improve an impaired coral reef to improve its ability to reduce wave energy reaching the shore, thus protecting a beach from erosion. Reef augmentation is a variation of reef restoration which involves placing physical structures (e.g. large boulders) on top of existing natural coral reefs to raise the height and reduce wave energy reaching the shore. New corals can be planted around the boulders, but if corals continue to suffer bleaching and die-back, there will continue to be a solid physical structure in place to act as a reef and protect the shore from wave action.
Dune restoration	Dune restoration refers to the rehabilitation of natural or artificial dunes to a better state of overall function, in order to gain the greatest coastal protection benefits. This is a technology aimed at reducing both coastal erosion and flooding in adjacent coastal lowlands. There are different methods depending on the site, e.g. building fences on the seaward side of an existing dune to trap sand and help stabilise any bare sand surfaces, or planting vegetation to stabilise natural or artificial dunes. This promotes the accumulation of sand from wind-blown sources around their stems – over time, this causes dune growth. Over time, dune vegetation root networks also help to stabilise the dune.
Wetland restoration	As a climate change adaptation measure for the coastal zone, wetland restoration is intended to reduce coastal flooding and erosion, but it can also provide new habitats and have other environmental benefits such as sediment trapping and filtration of river water before it reaches the sea. Wetland restoration relates to the rehabilitation of an impaired wetland to a better state. The most commonly restored wetland ecosystems for coastal protection in Seychelles are coastal freshwater marshes and mangroves. Seagrasses may also be employed as a coastal defence, to dampen waves but on their own they are seldom considered an adequate shore protection alternative Wetland habitats are important because they help to dissipate wave and tidal energy and act as a sediment trap for materials, thus helping to build land seawards and reduce erosion and protect against flooding. The restoration method adopted depends on the habitat being restored.
Flood gates / sluice gates	Storm surge barriers and closure dams are large-scale coastal defence projects, which provide a physical barrier, preventing storm surges from travelling upstream into rivers and estuaries. In Seychelles, the rivers are very small streams, but still vulnerable to storm surges which cause erosion of the banks, flooding and salt water intrusion upstream. Small structures such as flood gates or sluice gates let water out during times of heavy rain but restrict tidal water from surgig upstream. This helps to keep upstream water levels low and therefore minimises coastal flooding.
Coastal setbacks	This is a soft technology approach to encourage developments along the coast or rivers to respect a minimum horizontal and/or vertical setback from the high tide water mark or flooding level. The setback can take into account current risks from extremely high tides, storm surges or flooding risks but for longer term climate change adaptation the setback should be established further back/up to account for future changes in sea level rise or flooding levels.

Source: TNA project, www.climatechwiki.org

Technology fact sheets (TFS) were developed for each of these technologies to support stakeholders through the process of technology prioritization. The TFS for the first three prioritised technologies are provided in **Annex III**.

3.6 Criteria and process of technology prioritisation

During the first national workshop,[14] stakeholders agreed on the criteria and indicators listed in **Table** 10 for prioritising long-listed coastal adaptation technologies. The MCA framework developed by the MCA4Climate project (UNEP, 2011) was used as the starting point for discussions. The criteria and indicators shown in **Table 10** are the result of customising the MCA4Climate framework for Seychelles.

The criteria for the coastal zone sector are explained below:

Objective criteria

- **Financing**: The indicator is the direct cost (in SR) and the factors to consider included construction costs, labour, purchase of land, compensation, and operation and maintenance costs.
- **Economic**: The indicator is avoided damage (in SR) and the factors to consider included cost for fixing km of road, fixing houses, relocating people, compensation and insurance for loss & damage of property, loss of livelihood e.g. fishing or tourism activities on the beach.

Subjective criteria (informed expert opinions based on knowledge and experience of working group members).

- **Implementation barriers**: The indicator being ease of implementation, and the factors considered included existing laws and policies in place, precedence with implementation in Seychelles or region, existing expertise in Seychelles, familiarity with the technology, and availability of materials in Seychelles. Financial barrier is excluded from this indicator.
- **Climate related**: The indicator used was reduced vulnerability, and the factors considered for scoring included: the proven ability of the technology to control erosion/flooding, its potential to demonstrate tangible coastal protection results in a short time frame, at least by 2030.
- **Social**: This criterion used the indicator of level of community engagement, and the factors considered included whether the technology was culturally appropriate, promoted social inclusion and cohesion and provided opportunities for the local community to help or get involved in planning, construction or maintenance.
- **Environment**: This criterion used the indicator of co-benefits and the factors considered included whether it would contribute to GHG sequestration, improve habitat for wildlife, filter water, and reduce pollution (including aesthetic, chemical, air, water or sedimentation).
- **Institutional**: The group used capacity to enhance governance as the indicator and the factors considered included: potential number of stakeholder agencies involved, whether the technology would support and stimulate better policy and laws, and whether it would encourage better partnerships between government, civil society and the private sector.

Three different combinations of weightings for the indicators were agreed by stakeholders during the first national workshop and a follow up working group meeting held on 20 May 2016. Weighting 1 represents the primary weighting agreed by stakeholders, and the remaining combinations of weights were used for the sensitivity analysis in order to ensure that the MCA process was robust. If the same three technologies are prioritized as first, second and third in all three weighting scenarios, the MCA can be considered valid.

[14] The first national capacity building workshop was carried out 28 and 29 April 2016. Stakeholders were introduced to the TNA process, including technology identification and prioritisation, barriers analysis, and development of technology actions plans. Stakeholders initiated the process of technology identification, and identified criteria and indicators for prioritising technologies.

Table 10. Criteria and indicators for prioritising coastal adaptation technologies.

Criteria	Indicators	Units	Weighting 1	Weighting 2	Weighting 3
Financing needs	Direct costs	SR/$	0.2	0.25	0.1
Implementation barriers	Ease of implementation	Likert scale	0.05	0.05	0.05
Climate-related	Reduced CC vulnerability / enhanced resilience	Likert scale	0.2	0.2	0.25
Economic	Avoided damages / cost	SR/$	0.2	0.15	0.25
Environmental	Environmental co-benefits (#), including GHG sequestration	Number of benefits	0.1	0.2	0.15
Social	level of community engagement, incl. preserve cultural heritage	Likert scale	0.1	0.1	0.15
Institutional	Improve governance	Likert scale	0.15	0.05	0.05

Source: TNA project

3.7 Results of technology prioritisation

The Coastal Zone Technology Working Group met on 22 July 2016 to undertake the MCA exercise for prioritising coastal adaptation technologies. This work session took place following several bilateral stakeholder meetings and email exchanges to gather information about each one of the eight proposed technologies and their associated costs. The stakeholders made use of the TFS that were developed for each one of the eight long-listed technologies given in **Table 9**. The TFS for the top three prioritised technologies are given in **Annex III**.

A MCA calculator was customised for the coastal zone, and it is given in **Annex IV**. **Table 11** shows the results of technology prioritisation using MCA for the cohort of weights corresponding to 'weighting 1' in **Table 10**. Prior to being weighed, the scores were normalised on a MIN-MAX scale. Hence, the final scores given in **Table 11** are the product of the normalised scores and weights. The top three ranked technologies are: (1) mapping; (2) wetland restoration; and (3) river outlet improvement. The top three technologies were the same for all three weighting scenarios showing that the MCA results are robust. Although of less concern here, the rankings of the remaining technologies changed for different combinations of weights. This issue is further discussed below. However, the main stakeholders' perspectives on the three top ranking technologies are first discussed.

Table 11. Results of MCA for prioritising coastal adaptation technologies.

	CRITERIA AND INDICATORS								
	Financing	**Implementation Barriers**	**Climate-related**	**Economic**	**Social**	**Environment**	**Institutional**		
Coastal adaptation technology	Direct cost	Ease of implementation	Reduced vulnerability	Avoided damage	Level of community engagement	Co-benefits	Enhance governance	**TOTAL**	**RANK**
Mapping	18.7	11.3	20.0	8.5	2.5	10.0	9.5	**80.47**	**1**
Dune rehabilitation	20.0	9.0	10.0	0.0	3.8	6.7	9.5	**58.92**	**5**
Wetland restoration	19.6	9.0	15.0	3.9	3.8	10.0	8.0	**69.26**	**2**
Seawalls/revetment	14.5	13.5	18.0	4.5	2.0	0.0	8.0	**60.44**	**4**
Detached breakwater	17.5	7.5	15.0	2.8	2.3	0.0	7.0	**52.00**	**7**
Coral reef repair	17.9	7.5	15.0	3.0	2.5	3.3	9.5	**58.71**	**6**
River outlet improvement	16.5	13.5	15.0	8.5	2.0	0.0	8.0	**63.46**	**3**
Coastal setbacks	0.0	3.8	1.0	20.0	2.5	10.0	8.0	**45.25**	**8**

Source: TNA project

1. **Mapping** – This technology included many different types of mapping, including: flood mapping, mapping of coastal ecosystems (using LIDAR and drones), bathymetry and current mapping to better understand movement of waves and sand offshore in order to allow for better planning of coastal restoration and protection measures. While some mapping work (of all types) has been already carried out in Seychelles, it was not readily available in one centralised location. Further, very little mapping has been done to date except for specific sites where a development has been planned. Mapping is generally considered to be a basic necessity for the successful implementation of all other technologies. It can be implemented quite easily, given that several measures have already been put in place for overcoming the financial and human capacity barriers that the technology faces;

2. **Wetland restoration** – Although stakeholders generally agreed that wetland restoration was much more challenging than other coastal adaptation technologies, they also agreed that is was a technology worth investing in since it will help to address coastal flooding (precipitation, SLR, storm surges). In some places, wetland restoration would need to be implemented alongside other measures such as river outlet improvement and setbacks, as well as improving current laws and policies regarding wetland protection. Stakeholders agreed that although there is limited coastal land for restoring lost wetlands, there is great potential for working with private landowners and hotels to restore and improve the natural functioning of wetlands. This approach is already being tested on a small scale at one or two hotel sites; and

3. **River outlet improvement** – This is a technology that is already being addressed through several national projects following recent severe coastal flooding events. The MEECC's CAMS unit also already has a schedule and budget for the desilting of river mouths. Although this technology ranked third, it was agreed by the government focal person that this technology was already being taken care of through national programmes, and that the expertise and capacity to apply it already existed in the country. Therefore, this technology does not require the support of the TNA process to be implemented or scaled up.

The rankings of the middle three technologies were not as robust as those for the top three prioritised technologies or the two bottom-ranked technologies (detached breakwaters and coastal setbacks were ranked seventh and eighth, respectively, for all combinations of weights). For instance, the following variations in ranking were observed:

- Dune restoration ranked fourth in one (weighting) scenario and fifth in the other two scenarios (there are three scenarios with each one corresponding to a cohort of weights in **Table 10**);
- Seawalls ranked fourth in two scenarios and sixth in the remaining scenario; and
- Coral reef repair ranked fifth in one scenario and sixth in the other two scenarios;

Given this variability, stakeholders recommended dune restoration as the third prioritised technology. As discussed earlier, dune restoration has been tried by the government in combination with the construction of timber piling and even rock revetments in some places. This technology has great interest due to the added social benefits of providing additional space for people to enjoy the beaches, as well as an opportunity for revegetation along coastal areas. In many places, the potential for dune restoration is restricted by the presence of a road along the top of or just behind the dune. There is need for more research to design dune restoration projects that are effective and tailored to the specific locations where they are needed, with input from an improved mapping and modelling capacity in the country. Furthermore, dune restoration can be combined with other soft and hard technologies, including river outlet improvement and low seawalls.

Chapter 4 Technology prioritisation for the Water Sector

4.1 Introduction

The Seychelles is facing water security issues. It is recognised that current water supply on Mahé, Praslin and La Digue is insufficient to meet demand, now and in the future (MWH, 2015). Water security is a cross-cutting issue that affects all sectors of society. The inefficient allocation and use of water leads to opportunity costs in the form of lost economic production and societal welfare, which impacts on current and future generations. Although there is sufficient rainfall of the order of 2,369 mm (mean annual) per year, there is significant run off to the ocean, not enough capture and storage and important leakage in the distribution system. Increasing water demand from the residential, commercial, agriculture, and tourism sectors is exacerbated by changes in rainfall patterns (see section 1.4.1) and a limited water storage capacity.

The Public Utilities Corporation, PUC (Water Division) has the mandate to collect, store and distribute safe water in the country. Ninety five percent (95%) of homes are connected to the PUC treated water supply system, and the remaining households use river and/or rain water. Since 2005, PUC has commissioned a series of 6 reverse osmosis desalination plants on the main granitic islands (4 on Mahé, 1 on Praslin and 1 on La Digue) that provide water during drier periods (MWH, 2015). Seychelles has in recent years implemented water distribution restrictions during periods of extended drought. During these periods potable water is distributed to households by cistern, which is not a cost effective measure.

The country faces multiple challenges with managing water resources, such as very steep terrain that accelerates water run-off to the sea, limited availability of land that makes it difficult to have large scale storage facilities, and limited technical expertise to deal with water security issues. These challenges are compounded by the impacts of climate change and variability on precipitation. It is, therefore, not surprising that adaptation in the water sector features prominently in national policies, strategies and action plans as discussed in sections 1.3 and 1.4, and **Annex I**.

4.1.1 Current water demand

Currently, water supply in Mahé, Praslin and La Digue is insufficient to meet overall demand resulting in frequent supply interruptions. The PUC notes that even with planned capacity (supply) increases, there will be insufficient supply to satisfy future demands. This observation is consistent with the results of WEAP modeling summarised in **Table 4** and **Table 5**. The production of treated water has increased across all three islands since 2009, largely as a result of desalination plant production as indicated in **Table 12**. The annual average water consumption for the period April 2009 to May 2014 for Mahé, Praslin and La Digue was around 7,400,000 m^3 or 617,000 m^3 per month. Eighty five percent (85%) of this consumption was on Mahé, 10.5% on Praslin, and 4.5% on La Digue.

Table 12. Average monthly water production (m^3).

Year	Mahé	Praslin	La Digue
2009	771,768[15]	88,30115	29,18415
2010	918,778	-[16]	-[16]
2011	1,093,003	97,756	31,670
2012	1,111,462	126,210	39,727
2013	1,051,994	89,601	38,727
2014	1,152,328	98,111	38,029

Source: European Investment Bank, 2015

[15] No desalination production data available.
[16] No data available.

While domestic consumption represents the highest sectoral consumption in Mahé and Praslin, it is clear that there are differences between the islands, with Mahé and La Digue domestic consumption accounting for 48% and 35% of total consumption, respectively. Tourism consumption on Mahé accounts for 8% of total consumption only, whereas on La Digue and Praslin it is 36% and 22%, respectively.

Non-Revenue Water (NRW[17]) is recognised as an issue in Seychelles. Recent studies have estimated NRW to be between 40% and 60%, although higher values have been established in certain locations on Mahé (MWH, 2015). Eighty percent (80%) of these losses are estimated to be from leakage, while the remaining 20% are commercial losses. The PUC has targeted a reduction in NRW of 2,515,000 m^3 per year (Reference[18]). Combined losses for the three islands have changed from 31% to 53% to 45% in the 2009/2010, 2012/2013 and 2013/2014 hydrological periods, respectively.

4.1.2 Trend and Projections

There are numerous factors which influence current and future water demands, including economic, climate, socio-economic, demographic and demand management factors. If not accounted for, these factors have the capacity to distort water demand forecasts. An end-use-based water demand forecast was carried out in the Seychelles in 2015 for the period 2015 to 2030 (European Investment Bank, 2015). The results indicate that demand will increase from 13,051 Ml/annum (2015) to 15,803 Ml/annum (2030) for Mahé; 1,113 Ml/annum to 1,392 Ml/annum for Praslin; and 467 Ml/annum to 679 Ml/annum for La Digue. These represent increases of 21% for Mahé, 25% for Praslin and 46% for La Digue.

4.2 Key climate change vulnerabilities in the water sector

The IPCC AR5 mentions that there was ‘high confidence, robust evidence, high agreement’ that current and future climate-drivers of risk for small islands during the 21st century include SLR, tropical and extra-tropical cyclones, increasing air and sea water temperatures, and changing rainfall patterns (Nurse *et al.*, 2014). The report also mentions with ‘high confidence’ that SIDS do not have uniform climate change risk profiles. Rather, their high diversity in both physical and human attributes and their response to climate-related drivers means that climate change impacts, vulnerability, and adaptation will be variable from one island region to another and between countries in the same region. It is therefore necessary to assess climate change at the local level, hence making the downscaling of GCMs very pertinent to SIDS. The results of the downscaled modeling of GCMs are discussed in section 1.4.1, and are not repeated here. But it is important to note that the TNA project has ensured locally-contextualised technology transfer options in order to adequately integrate adaptation planning in the water sector. This is in response to the IPCC AR5 which noted that the diversity in potential response in SIDS had not always been adequately integrated in adaptation planning (Nurse et al., 2015, pg. 1616).

Climate change will increase the natural variability of rainfall patterns and is likely to generate more extreme events, such as floods and droughts. These phenomena are expected to have significant effects on water safety and security, altering patterns of availability and distribution, and increasing water contamination especially in a context of increased demand due to population growth and economic development. Results from four global circulation models carried out during the SNC (Government of Seychelles, 2011b), indicate that climate change is expected to increase the severity of water shortages on Mahé, Praslin and La Digue because of the following factors (i) decreases in rainfall during the dry southeast monsoon which will reduce stream flow, groundwater recharge and therefore water supply; (ii) increases in surface-air temperatures which will increase rates of evapo-transpiration and consequently reduce stream flow, ground water recharge and further exacerbate the

[17] **Non revenue water** (NRW) is water that has been produced and is “lost” before it reaches the customer. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example through theft or metering inaccuracies).

[18] Baseline water forecast demand report, 2015 ,European union

water supply problem; and (iii) increases in rainfall intensity which will result in greater surface runoff and reduced water capture in existing storage facilities.

The results of WEAP modeling discussed in section 1.4.1 show that the combination of likely climate fluctuations, high population growth and economic development results in unmet water demand of 4879, 5297, 6151, 8058 and 9565 million litres for the years 2010, 2015, 2020, 2025 and 2030, respectively. These figures have highlighted the drastic increase in the deficit of water which fundamentally poses a serious risk to the sustainable development of the country.

4.3. Decision context

4.3.1 Existing national policies related to the water sector, to climate adaptation and technologies innovation

There are several national policies and instruments such as the legal framework that support adaptation in the water sector. There are also ongoing initiatives that are complementary to the TNA project. The policies, legal frameworks and adaptation initiatives are reviewed below.

4.3.1.1 The Policy Framework in the water sector

The main policy documents related to the water sector are:

The ***Seychelles Sustainable Development Strategy, SSDS*** (2012-2020) recognises water management as a priority for Seychelles. The SSDS indicates that although there is sufficient annual rainfall (2,369 mm per year on average) to provide an adequate water supply to the granitic islands, the capacity to retain or capture this water to meet national demand remains inadequate. Combined with an old distribution network, the challenges of water management, especially during dry periods, are becoming very difficult. Climate change will also significantly affect the country's ability to provide adequate treated water, although more than 95% of the population is connected to the treated water supply.

The most densely urbanized areas of Mahé, including Victoria and suburbs and north western area, are connected to the water sewage and treatment network of Providence or Beau Vallon. The rest of Mahé, Praslin and la Digue relies on decentralised conventional treatment system (septic tanks), which is not sustainable for the rising number of households and businesses. With such limited sewage coverage, the water quality of most rivers is deteriorating.

The main challenges facing the sector are (Government of Seychelles, 2009):

- ✓ The lack of adequate capacity for capture and storage of potable water;
- ✓ The high cost of water infrastructure – new dams, desalination plants or reservoirs and replacement of ageing distribution network;
- ✓ Pollution arising from ageing sewer systems and lack of appropriate sewerage treatment systems for a large part of the population; and
- ✓ Lack of human capacity to manage water and sanitation.

The SSDS has identified several goals for sustainable fresh water management, including:

- **Goal 1**: Promote measures to reduce demand:
  - Objective 1.1: Reduce water demand and subsequent consumption.
- **Goal 2**: Promote sustainable measures to increase potable water supply to the population:
  - Objective 2.1: Increase water supply through future sustainable source developments.
  - Objective 2.2: Increase water supply through improvements of safe yield of existing water sources.
  - Objective 2.3: Increase water supply through improvements to the transmission / reticulation systems.
  - Objective 2.4: Increase water supply through improvements to water treatment works.

- **Goal 3**: Establish effective integrated water management system:
    - Objective 3.1: Improved institutional capacity and human resources.

The ***Seychelles Strategic Plan, SSP*** **(2015-2040**) (Government of Seychelles, 2015b) proposes:

1. **A Water Framework** based on a hierarchy of priorities for water provision in Seychelles, which seeks to encourage demand reduction with regard to water supply, and to maximise efficiency of the transmission network through reducing leakages from existing pipes.

   The current water network efficiency is as low as 50%, with approximately 25% of this water lost through pipe leakages. Steps have already been taken to investigate water loss during transmission, and investment in recent years to reduce leakage has had a significant effect. Future upgrades will focus on investigating the asbestos cement pipes, which are believed to be the oldest pipes in the network and are also highly susceptible to degradation under high flow conditions. The priority area for upgrade is Victoria and the surrounding suburbs where the largest population and the oldest network are found.

   Should capacity constraints remain after the necessary upgrades to the water distribution network, it may be necessary to upgrade existing or provide additional water supply infrastructure. Given the cost of new water storage facilities, the Government of Seychelles will seek the upgrade of existing facilities first. Work is already undergoing to raise the height of the dam at La Gogue to increase water storage capacity. Beyond this the construction of additional reservoirs and associated water treatment plants will be supported where the need can be demonstrated. The Government of Seychelles is also committed to minimising the environmental impacts of water supply, which will be reflected in a move away from desalination. Potential sources of groundwater and opportunities for groundwater recharge across Seychelles will also be explored, whilst ensuring there is a reduction in over-abstraction of groundwater (Government of Seychelles, 2015b).

2. **A Wastewater Framework** that aims to provide a localised, distributed wastewater network. It is based on the policy requirement that all development in areas of more than four dwellings per hectare should be connected to a localised sewerage system.

The ***Seychelles Water Supply Development Plan 2008-2030*** (Government of Seychelles, 2008) provides detailed information on the water situation in the Seychelles and various projects aimed at modernising the water infrastructure in the Seychelles. It is estimated that there will be an acute water deficit by 2030 that could reach for a low demand scenario of 28,319 m^3 per day and for a high demand scenario of 40,216 m^3 per day. The recommended water demand management measures are listed in **Table 13**.

Table 13. Water demand management measures in the Water Supply Development Plan.

Description	Recommendations
By-Laws	Strengthening of regulations under the PUC Act
Metering	- Improving metering practice - Application of suitable water tariffs - Printing water conservation data on the monthly water bills
Pressure Management	- Undertaking a programme of pressure reduction through network analysis - Using meter data to assess the impact of reduced pressure on demand
Water Saving Devices	- Offering and widely distributing a selection of free water reduction devices - Offering for sale water efficient equipment and promote their sale using the internet as well as mail shots
Promotional Literature	- Redeveloping the PUC website to give a wider range of information and ensuring that it is more dynamic in providing customer information - Improving the quality of brochures offered to customers and ensuring much greater distribution
Public Awareness	- Developing a positive marketing plan to communicate the proposals for rectifying the public perception of water shortages

	- Creating local water conservation groups to help disseminate the water conservation message to the public
School Education	- Creating an agreement with the Ministry of Education to introduce water into the school curriculum - Using an educational consultant to prepare the teaching materials from previously published materials - Introduce the teaching into schools as soon as possible
Water Re-Use	- Actively promote the use of simple grey water during dry season - Providing rainwater harvesting advice for use during the end of the rainy season and the start of the dry season - Investigating the possibility of making use of the final effluent to augment raw water supplies
Existing Rivers Committee Structure	Integrated River Basin Management(IRBM) - The current Rivers Committee should act at a strategic level setting policy and ensuring that the actions required are implemented - All the stakeholders should be engaged in the process of improving the current situation and setting goals for the future - Setting-up of a small enforcement team by the Ministry of Environment to monitor and control the various aspects of the IRBM **Drinking Water Safety Plans (DWSPs)** -The current rivers committee should act as the coordinating body to implement the Drinking Water Safety Plan objectives :G - To minimise the contamination of water sources - To reduce or remove any contamination by using appropriate treatment - To prevent contamination as the water passes through the distribution system to the point of supply

Source: Government of Seychelles, 2011

The water supply measures recommended in the Seychelles Water Supply Development Plan are given in **Table 14**.

Table 14. Water supply management measures in the Water Supply Development Plan.

Description of water supply management measure
Water treatment plants rehabilitation (Hermitage, Cascade, le Niol , Rochon and mare aux cochons)
Rehabilitation and installation of Pumping stations and water tanks
Replacement of poor performing pipelines and laying of new pipelines
Installation of desalination plants
Raising existing dam (La Gogue Dam)
Building new dams (Grand Anse and Plaine Hollandaise)

Source: Government of Seychelles ,2011

The ***Sanitation Master Plan*** is being developed and will provide the main strategy for sanitation services in Seychelles. It will promote innovative and alternative approaches to sanitation within the general framework of the urban planning on the three main islands. Further, it will ensure optimisation links with other sectors through an integrated approach.

Currently, there is as yet no clear strategy for the provision of sanitation services although significant investment was made in the sewerage network to cover densely populated areas in the north of Mahé and around Victoria. Sanitation on the rest of Mahé, Praslin and la Digue relies on decentralised conventional treatment system (septic tanks) which is not sustainable for the rising number of households and businesses. With such limited coverage, the water quality of most rivers is deteriorating.

The National Science, Technology and Innovation Strategy is being developed by the National Institute of Science, Technology and Innovation (NISTI), which is a newly-enacted body under the

Ministry of Investment, Entrepreneurial Development and Business Innovation. It has an oversight and leadership mandate with regards to the growth and development of science, technology and innovation across all sectors and programmes, and has potential to contribute to climate change mitigation and adaptation action. Also of interest, is its mandate to assist the transition to a Seychelles knowledge-based economy between now and 2026. However, NISTI has limited financing means and limited institutional and technical capacity.

4.3.1.2 The Legal Framework in the water sector

The legal framework for the water sector is shaped by several legislations, including among others:

The **Public Utilities Corporation (PUC) Act (1985):** The management of the water resources falls under the responsibility of a parastatal Agency, namely: the Public Utilities Corporation (PUC) which is under the aegis of MEECC. PUC implements the Public Utilities Corporation Act that also provides water supply standards. The PUC has the responsibility to supply treated domestic water to all Seychellois in accordance with international standards for potable water.

The **State Land and River Reserves Act** (Cap 150) of 1903 establishes the role for forest rangers, and establishes the concept of watershed protection zones along rivers and rivulets. It is somewhat outdated and is not being implemented.

Different elements of water management are also contained in the following legislation:

- The Public Health Act (Act 18 of 1960);
- The Town and Country Planning Act (Act 21 of 1972);
- The Environmental Protection Act (Act 71 of 1995);
- The Disaster Risk Management Act (Act 15 of 2014); and
- The Water Act (Act 21 of 1982), which was superseded by the PUC Act 1985.

The current legal framework does not provide an umbrella legislation that outlines how the nation's water resources are to be protected, used, developed, managed and controlled in a way that takes account of efficiency, equity and sustainability, and that ensures public involvement in decision-making around water use, allocation and protection. The Public Utilities Corporation (PUC) Act is mainly a water services act. For instance, it makes provision for water supply and sanitation, but it does not *explicitly* include provision for the efficient, equitable or sustainable use of water.[19] Further, there is no existing national water policy for the Seychelles. This hinders progress towards integrated water management and the institutional strengthening required to deliver it.

4.3.1.3 On-going initiatives

Some of the initiatives supporting coastal adaptation listed in **Table 7** also have co-benefits for the water sector. The Adaptation fund-financed, UNDP-implemented ***ecosystem based watershed project*** is addressing water supply from an ecosystem perspective. The project objective is to reduce climate change vulnerabilities by spearheading EBA as climate change risk management to restore ecosystem functionality, and to enhance ecosystem resilience and sustaining watershed and coastal processes in order to secure critical water provisioning and flood attenuation ecosystem services from watersheds and coastal areas.

The project entitled, "***Implementing Integrated Water Resource and Wastewater Management in Atlantic and Indian Ocean Small Islands Developing States*** (AIO IWRM SIDS)" is a Global Environment Facility (GEF) funded project and implemented by UNEP. The project is focusing on integrated water resources management (IWRM), water use efficiency plans and water supply and sanitation. A pilot project on La Digue is currently being implemented.

[19] Reference is made to licensing and abstraction, but efficiency, equity and sustainability are not explicitly mentioned in the Act.

PUC is also implementing a project funded by loans from the European Investment Bank and Agence Française de Développement. It is designed to address deficiencies in water security by increasing efficiency in the distribution system and reducing demand from consumers. A further loan and grant of about EUR 20 million from the African Water Facility of the African Development Bank will help the Government to finance part of the Mahé Sustainable Water Augmentation Project and meet the targets set out in the Water Supply Development Plan 2008-2030.

4.4 Overview of Existing Technologies in the Water Sector

Table 15 provides an overview of the technologies that have been used in the water sector in Seychelles.

Table 15. Technologies used in the water sector.

Technologies	Description
Desalination	Since 2005, desalination plants with reverse osmosis technology have been used in Seychelles by the PUC and a few large private companies in the tourism sector (e.g. Ephelia, Alphonse, Desroches, etc), and the fish processing sector (e.g. IOT). The production capacity of plants varies from 2,500 m^3 to 5,000 m^3 per day.
Dam	Situated in the north of Mahé, la Gogue Dam, built in 1976, has a capacity of 850,000 m^3. Le Rochon Dam on Mahé has a smaller capacity of 50,000 m^3. Scarcity of land made it difficult to have more dams. The height of la Gogue Dam is being raised to increase storage capacity.
Leakage management system	NRW was estimated at around 50% of water inputs. Eighty percent (80%) of NRW is due to physical water losses, and the remaining 20% are commercial losses. For many years there was no systematic approach to leakage management. In 2014, PUC has adopted an ambitious leakage management plan which is currently being implemented.
Rooftop rainwater harvesting	Simple roof collection systems – including the roof catchment area, guttering and piping that lead to a storage tank and the fittings within the storage tank - are in limited used in the Seychelles. Only 4.5% of households in Seychelles have rainwater harvesting tanks, while 47.1% of households have a water storage tank (National Bureau of Statistics, 2012). Larger systems for commercial and government properties are more complex, whereby water is collected and stored in sub-surface tanks, treated and then pumped for non-potable use. These more complex systems are in marginal use in the Seychelles (e.g. Bird Island, Bebi Guesthouse on La Digue).
Water efficient fixture and appliances	Water efficient appliances have recently appeared on the local market mainly for flush toilets, shower and washing machines. There are three local suppliers selling these items. However, the market penetration is low. Water efficiency labeling is yet to be adopted. A subsidised loan scheme was set up in 2014 for such appliances, but it remains poorly utilised by the population.
Ground surface rainwater harvesting	Land surface catchment – i.e. collecting water from a large surface area and usually stored for agricultural purposes - is marginally used in Seychelles. This approach has been adopted in Seychelles at Anse Soleil Rock Barrage and La Digue l'Union Estate.
Groundwater exploitation	Water drilling started in the Seychelles in 1970's on Praslin and La Digue. Around 30 drillings were done on Mahé and 10 drillings on Praslin with depth varying between 7.5 m and 255 m (average depth of 90 m). Only one bore hole is currently being exploited by PUC on the two islands. Ground water is being exploited on La Digue with a maximum yield of 500 m^3/day. The potential for using ground water could increase with the introduction of the managed recharge aquifer approach.

Source: TNA project

4.5 Adaptation technology options for the water sector and their main adaptation benefits

The pre-screening of the technologies was carried out by the water sector adaptation consultant, and the technical feasibility and adaptation benefits of 18 potential adaptation technologies were discussed with stakeholders (please see Annex II for the list of stakeholders consulted). As a result of the working group discussions and follow up bilateral discussions with stakeholders, a list of nine technologies was retained for the MCA as indicated in **Table 16**. Technology fact sheets were developed for each technology. The TFS for the top three prioritised technologies are found in **Annex III**.

Table 16. Climate change adaptation technology options for the water sector and their benefits.

Technologies	Climate change Adaptation benefits
Desalination 	Desalination contributes to climate change adaptation through diversification of water supply and resilience to water quality degradation. Desalination provides water supply during drought periods and during floods when water is contaminated. PUC is targeting to increase production of potable water from desalination by 15,000 m^3/day in order to be able to match water demand and enhance water security.
Leakage management in piped systems 	Detection and repair of leaks in water systems is an important part of a comprehensive strategy to reduce pressure on existing water resources. As discussed above, NRW is recognised as an issue in Seychelles.
Rainwater harvesting with water treatment and safe storage 	Rainwater harvesting (RWH) contributes to climate change adaptation at the household level primarily through two mechanisms: (1) diversification of household water supply; and (2) increased resilience to water quality degradation. RWH effectively increases per capita water availability. In parallel, household water treatment and safe storage increases resilience to water quality degradation by enabling users to improve water quality at the point of use. RWH practice is currently limited in the Seychelles. The aim of the government is to target equipping all households with RWH and water treatment system.
Water reclamation and reuse 	Water reclamation and reuse contributes to climate change adaptation by allowing water resources to be diversified and conserved. Using reclaimed water for applications that do not require potable water can decrease the depletion of protected water sources. Water reuse is very limited in the Seychelles.
Water efficient fixtures and appliances 	Water conservation is an essential part of any comprehensive strategy to reduce pressure on existing water resources. Therefore, residential water conservation efforts can make a positive contribution to reducing pressure on water resources. The objective of the government is to target all households.
Ground surface rainwater harvesting 	Lack of adequate water supply during drought and seasonal dry periods can halt economic development and have a significant impact especially in the agricultural sector. This technology can help the agricultural sector to have a constant and regular water supply for agricultural production thereby minimising the impact of climate change on crop and livestock production.

Exploitation of groundwater with managed recharged aquifer 	Water supply can be diversified by harvesting water from aquifers. Groundwater resources are marginally exploited in Seychelles. There is potential to use groundwater resources with the careful management of aquifer recharge. This technology will increase water storage during rainy periods and provide water during the dry periods.

Source: TNA project

4.6 Criteria and process of technologies prioritization

In order to prioritise the adaptation technologies (**Table 16**), a set of criteria and indicators were locally-validated using the MCA4Climate as the starting framework (UNEP, 2011). The criteria and indicators used for MCA for adaptation options in the water sector and the scoring scale for quantifying each indicator are summarised in **Table 17.**

The criteria for the water sector are discussed below:

Objective criteria

- **Financing**: The indicator is the direct cost (in SCR) and the factors to consider included construction costs, labour, cost of equipment
- **Economic**: The indicator is catalysing private investment and the factors to consider are the potential percentage of private investment that can be mobilised to adopt and upscale the technology proposed and the value of the water savings potentially made by adopting the technology.

Subjective criteria (informed expert opinion based on knowledge and experience of working group members)

- **Implementation barriers**: The indicator being ease of implementation, and the factors considered included existing laws and policies in place, precedence with implementation in Seychelles or region, existing expertise in Seychelles, familiarity with the technology, and availability of materials in Seychelles.
- **Climate related**: the indicator used was reduced vulnerability, and the factors considered for scoring included the proven ability of the technology to increase water availability and quality in a context of increase climate variability in a short time frame.
- **Social**: This criterion used the indicator of level of community engagement, and the factors considered included whether the technology was culturally appropriate, promoted social inclusion and cohesion and provided opportunities for the local community to help or get involved in planning, construction or maintenance.
- **Environment**: This criterion used is the indicator of the number of co-benefits and the factors considered included: whether it would contribute to GHG sequestration, GHG Reduction, resilient river ecosystems, management of invasive alien species and reduce pollution.
- **Institutional**: The group used capacity to enhance government as the indicator and the factors considered included: potential number of stakeholder agencies who would be involved, whether the technology would support and stimulate better policy and laws, and whether it would encourage better partnerships between government, civil society and the private sector.

Three different combinations of weightings for the indicators were agreed by stakeholders during the first national workshop and a follow up working group meeting. Weighting 1 represents the primary weighting agreed by stakeholders, and Weighting 2 and Weighting 3 were used for the sensitivity analysis, to ensure that the MCA process was robust. If the same three technologies are prioritised as first, second and third in all three weighting scenarios, the MCA can be considered as valid.

Table 17. Criteria and indicators for prioritising water sector adaptation technologies.

Criterion	Indicators	Units	Weighting 1	Weighting 2	Weighting 3
Financing needs	Direct costs	SR	0.2	0.15	0.25
Removal of barriers	Ease of implementation	Likert Scale	0.1	0.05	0.15
Climate-related	Reduced CC vulnerability / enhanced resilience	Likert Scale	0.15	0.1	0.2
Economic	Catalysing private investments	Likert scale	0.1	0.15	0.05
	Value of water savings	SR	0.2	0.25	0.15
Environmental	Environmental co-benefits (#) (e.g. GHG sequestration, GHG reduction, resilient river ecosystems, management of invasive alien species)	Number of benefits	0.15	0.1	0.05
Social	Level of community engagement	Likert scale	0.05	0.1	0.05
Institutional	Improve governance	Likert scale	0.05	0.1	0.1

Source: TNA project

Scoring: The indicators *ease of implementation, reduced climate vulnerability, catalysing private investment, level of community engagement, and improved governance* were scored on a Likert scale: 1 (lowest) to 10 (highest). All the other indicators were quantified. All the scores were then normalised on a MIN-MAX scale before applying the weights shown in **Table 17** (see below). Regarding *ease of implementation*, the technology which was deemed easiest to implement was assigned a higher value.

Weightage: In order to minimise bias, the weights used in the MCA exercise were assigned only after stakeholders had completed the scoring process. Members of the water working group considered that *direct costs*, *value of water savings* and *reduced climate vulnerability* were three very important factors, and therefore received the highest weightage across all three sets of weights. MCA was carried out and the weightage was subjected to sensitivity analysis in order to highlight the importance of the weighing factor on the prioritisation of technologies. The set of weights used for sensitivity analysis reflects the choice of the working group to balance the social and environment criteria in the analysis.

Combining weights and scores: A linear additive model was used to work out the total weighted score for each technology. The score for a given criterion was multiplied by the weightage associated with that particular criterion to obtain a weighted value. This was repeated for all the technologies and the ranking was carried out as per the weighted scale, with the topmost being the technology having the highest score.

4.7 Results of technology prioritisation

A MCA calculator was customised to prioritise technologies in the water sector (please see **Annex IV**). **Table 18** shows the results of technology prioritisation using MCA for the set of weights corresponding to 'Weighting 1' in **Table 17**. Prior to being weighed, the scores were normalised on a MIN-MAX scale. Hence, the final scores given in **Table 18** are the product of the normalised scores and weights. The top three ranked technologies are: (1) rooftop rainwater harvesting with water treatment and safe storage; (2) water efficient fixtures and appliances; and (3) ground surface rainwater harvesting. Sensitivity analysis was carried out using the different sets of weights shown in **Table 17**. The technology ranks were the same for all three sets of weights showing that the MCA results are robust. The only exception was the reversal in ranking of ‘leakage management’ and ‘water reuse (domestic)’ when the set of weights corresponding to ‘Weighting 2’ in **Table 17** was used.

Table 18. Results of MCA for prioritising water sector adaptation technologies.

	CRITERIA AND INDICATORS									
	Financing	Implementation Barriers	Climate-related	Economic		Social	Environment	Institutional		
TECHNOLOGY	Direct cost	Ease of implementation	Reduced vulnerability	Catalysing private investments	Value of water saved	Level of community engagement	Co-benefits	Enhance governance	TOTAL	RANK
Desalination	0.0	1.5	15.0	0.0	3.0	0.0	0.0	0.0	**19.48**	**7**
Leakage Management	19.9	4.5	15.0	0.0	6.5	3.5	10.0	0.0	**59.42**	**4**
Rooftop Rainwater Haversting with water treatment	14.4	5.0	11.3	7.5	20.0	4.5	15.0	3.8	**81.35**	**1**
Water Reuse domestic	10.0	2.0	13.5	5.0	2.1	2.5	15.0	5.0	**55.09**	**5**
Water Efficient Appliances	18.0	8.0	13.5	10.0	2.6	5.0	10.0	3.8	**70.86**	**2**
Ground Surface Rainwater Harversting	20.0	5.0	11.3	5.0	1.2	2.5	15.0	3.3	**63.22**	**3**
Ground water resources	19.9	4.5	13.5	0.0	0.0	0.8	5.0	0.0	**43.60**	**6**

Source: TNA project

The prioritised adaptation technologies were agreed by all members of the working group. While they all appear to focus on the hardware component of a technology, the consensual view was that the technology actions plans that will be developed for the prioritised technologies will, where applicable, also cover the accompanying software and orgware components of the technologies. The perspectives of stakeholders on the three technologies are summarised as follows:

1. **Rooftop rainwater harvesting with water treatment and safe storage -** RWH is not commonly practiced in Seychelles. It can contribute to reducing climate vulnerability at the household level primarily through two mechanisms: (1) diversification of household water supply; and (2) increased resilience to water quality degradation. This adaptation technology is based on encouraging each household to have a rainwater harvesting system with appropriate water treatment and water storage;

2. **Water efficient appliances and fixtures –** Stakeholders argued that water use efficiency was an essential part of any comprehensive strategy to reduce pressure on existing water resources. Residential water conservation efforts can make a positive contribution to reducing pressure on water resources. This is particularly important since as discussed in section 4.1.1, the residential sector is the highest end-use sector in Seychelles. This adaptation technology is based on encouraging each household to have water efficient devices and fixtures installed;

3. **Ground surface rainwater harvesting –** Stakeholders argued that this technology can be applied in the agriculture sector. It can help the agricultural sector to have a constant and regular water supply for agricultural production thereby minimising the impact of climate change on crop and livestock production. This adaptation technology is based on improving storage of surface runoff water by building gabions structures.

Chapter 5 Summary and Conclusions

5.1 Coastal Zone

For the coastal zone sector, a technology working group (TWG) was assembled bearing in mind local expertise in technologies to address coastal flooding and erosion. The members of the TWG were drawn from government, civil society and the private sector. The following meetings were held with the TWG coastal sector:

- TNA workshop held 28-29 April 2016 - The long list of technologies was drawn, and stakeholders reviewed a shortlist of 10 technologies most applicable to Seychelles. Stakeholders also discussed and agreed on the criteria and indicators that are to be used in technology prioritisation using MCA;
- TWG meeting 31 May 2016 - Members of the TWG finalised the short list of technologies, discussed the merits of each technology and their status in the country, and shared contacts of organisations likely to have more information about technology costs and existing projects; and
- TWG meeting 22 July 2016 – members of the TWG were convened to carry out MCA for prioritising coastal adaptation technologies. Prior to this working group meeting, bilateral meetings or exchanges by email were held with selected stakeholders.

In between the above meetings, members of the TWG were regularly updated on the progress of the technology identification and prioritisation process. The technology fact sheets (TFS) were also developed in close consultations with the members of the TWG. This participative and inclusive approach allowed stakeholders to participate and share their views and information about the technologies, even if they were not able to attend the meetings.

A copy of the MCA calculator (see **Annex IV**) and results of coastal adaptation technology prioritisation was shared with the members of the TWG for validation. The criteria and indicators used for the MCA exercise for the coastal zone sector were customised using the MCA4Climate framework as the starting point. The sensitivity of technology ranking on weights was carried out for three different sets of weights. The weights were assigned by the members of the TWG, and were found to have no bearing on the rankings of the top three prioritised technologies, implying that the MCA results were robust.

The top three ranked coastal adaptation technologies from MCA are:

4. Mapping
5. Wetland restoration
6. River outlet improvement

However, because the government is already investing heavily in river outlet improvement and the expertise already exists in the country, it was proposed to instead adopt dune restoration as the third prioritised technology. The revised list of prioritised coastal adaptation technologies that will be used for carrying out barriers analysis and development of technology action plans for the coastal zone sector are:

1. **Mapping** – This technology includes flood mapping, mapping of coastal ecosystems (using LIDAR and drones), bathymetry and current mapping to better understand movement of waves and sand offshore in order to allow for better planning of coastal restoration and protection measures. Mapping is generally considered to be a basic necessity for the successful implementation of all other technologies for protection of the coastal zone. It can

be implemented quite easily, given that several measures were put in place for overcoming the financial and human capacity barriers that the technology faces.

2. **Wetland restoration** – Wetland restoration will help to address coastal flooding (precipitation, SLR, storm surges). In some places, wetland restoration would need to be implemented alongside other measures such as river outlet improvement and setbacks, as well as improving current laws and policies regarding wetland protection. There is great potential for working with private landowners and hotels and communities to restore and improve the natural functioning of coastal wetlands.

3. **Dune Restoration** –Dune restoration has been tried to some extent by the government but needs further development. This technology has great interest due to the added social benefits of providing additional space for people to enjoy the beaches, as well as an opportunity for revegetation along coastal areas. There is need for more research to design dune restoration projects that are effective and tailored to the specific locations where they are needed, with input from an improved mapping and modelling capacity in the country. Furthermore, dune restoration can be combined with other soft and hard technologies, including river outlet improvement and low seawalls.

5.2 Water Sector

For the water sector, a TWG composed of key stakeholders from government, civil society and experts from donor-funded projects was set up in April 2016. The following meetings were held:

- TNA workshop on 28-29 April 2016 - Stakeholders discussed and selected the criteria and indicators used in the MCA for prioritising adaptation technologies in the water sector. Stakeholders also started the process of assigning weights to the criteria and indicators. The approach to customise the MCA calculator was the same as for the coastal zone sector;

- Bilateral meetings were held to finalise the short list of technologies that should be included in the prioritisation process. Technology fact sheets were developed for each technology in consultation with stakeholders; and

- TWG meeting 15 June 2016 – Members of the TWG reviewed and vetted the calculations made to quantify the objective indicators used in MCA. Members of the TWG used a consensual approach through discussions to score the qualitative indicators on a Likert scale.

The participative and inclusive approach adopted was the same as that used for the coastal zone sector. The MCA process was iterative, and three revisions of the MCA results were carried out as more information was made available. Hence, members of the TWG were able to reflect on their scores and adjust their positions as they became more familiar with the TNA process, tools and methodologies.

Sensitivity analysis showed that the change in sets of weights did not influence in the ranking of the top three prioritised technologies. This provided confidence that the results of the MCA were robust. The top three ranked water sector adaptation technologies are:

4. **Rooftop rainwater harvesting with water treatment and safe storage**: This climate change adaptation technology is based on encouraging each household to have a rainwater harvesting system with appropriate water treatment and water storage which is currently not universally used in the Seychelles (less than 5 % of household have installed the technology). This technology is a priority because it has potential for scaling up and can contribute significantly to reducing climate vulnerability at the household level primarily by diversifying household water supply; and by increasing resilience to water quality degradation.

5. **Water efficient appliances**: The residential sector is the highest end-use sector in Seychelles. Residential water conservation efforts can make a positive contribution to reducing pressure on water resources. However, the market penetration of water efficient appliances is low and its utilization is poor. Encouraging each household to have water efficient devices with the appropriate framework is a national priority to reduce pressure on water resource and increase climate resilience of the population.

6. **Ground surface rainwater harvesting**: Lack of adequate water supply during drought and seasonal dry periods can have a significant economic impact in the agricultural sector. Ground surface runoff water is important in the Seychelles because of its geology, topography and rainfall patterns. This technology based on improving storage of surface runoff water by building gabion structures is a priority for the agricultural sector to have a constant and regular water supply thereby minimising the impact of climate change on crop and livestock production and improving the food security situation in the Seychelles.

List of References

Adonis, G., Zarine, W. 2014. *Application of a Vulnerability Resilience Profile (VRP) to Long-Term, Integrated Sustainable Development Planning: Republic of Seychelles*.

Dhar, S., Painuly, J. Nygaard, I., and Rogat, J. 2014. *Organising the National TNA Process: An Explanatory Note*, UNEP DTU Partnership.

Edwards, A.J., Gomez, E.D. 2007. *Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme*: St Lucia, Australia. iv + 38 pp

Environment Agency, UK. 2015. *Cost estimation for coastal protection: summary of evidence (Report SC080039/R7). Flood and Coastal Erosion Risk Management Research and Development Programme*. Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/411178/Cost_estimation_for_coastal_protection.pdf.

European Investment Bank. 2015. *Water Baseline Demand Forecast Report*.

Ferrario, F. et al. 2014. *The effectiveness of coral reefs for coastal hazard risk reduction and adaptation*. Nat. Commun. 5:3794 doi: 10.1038/ncomms4794.

Government of Seychelles. 2005. *Seychelles National Wetland Conservation and Management Policy*.

Government of Seychelles. 2008. *Seychelles Water Supply Development Plan 2008 – 2030*.

Government of Seychelles. 2014. *Seychelles' National Disaster Risk Management Policy*. Division of Risk and Disaster Management, Seychelles.

Government of Seychelles. 2015a. *Seychelles Intended Nationally Determined Contribution (INDC) under the United Nations Framework Convention on Climate Change (UNFCCC)*.

Government of Seychelles. 2015b. *Seychelles Strategic Plan 2015-2040*.

Government of Seychelles. 2015c. *National Development Strategy 2015-2019*.

Government of Seychelles. 2011a. *Seychelles Sustainable Development Strategy 2011-2020*.

Government of Seychelles. 2011b. *Seychelles' Second National Communications under the United Nations Framework Convention on Climate Change*: Ministry of Home Affairs, Environment, Transport and Energy, Seychelles.

INGC. 2009. *INGC Climate Change Report: Sea Level Rise and Cyclone Analysis*, p.33-66.

Japan International Cooperation Agency (JICA). 2013. *Final report: Project for the study of coastal erosion and flood control management in the Republic of Seychelles*. Ministry of Environment and Energy, Seychelles.

Klemas, V.K. 2015. *Coastal and Environmental Remote Sensing from Unmanned Aerial Vehicles: An Overview*. Journal of Coastal Research, 31(5). pp. 1260-1267.

Marcaccio, J., C. Markle and P. Chow-Fraser. 2015. *Unmanned aerial vehicles produce high-resolution, seasonally-relevant imagery for classifying wetland vegetation*. International

Conference on Unmanned Aerial Vehicles in Geomatics, 30 Aug–02 Sep 2015, Toronto, Canada. Retrieved from: http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-1-W4/249/2015/isprsarchives-XL-1-W4-249-2015.pdf .

Mendez, J.H.S. et al. 2013. *Analysis of sea level rise and coastal flooding in the Seychelles islands due to climate change. Current scenario and future projections for 2025, 2050 and 2100*. Republic of Seychelles.

Milano,G.R. 2000. *Island restoration and enhancement in Biscayne Bay, Florida*, 1-17. In P.J. Cannizarro (ed.). Proceedings of the 26th Annual Conference on Ecosystem Restoration and Creation. Hillsborough Community College, Tampa, Fl.

Moustache, A.M. 2015. *Adaptation to Impacts of Climate Change on the Food and Nutrition Security Status of a Small Island Developing State: The Case of the Republic of Seychelles*. in Impacts of Climate Change on Food Security in Small Island Developing States, Wayne Ganpat and Wendy-Ann Isaac (Eds). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-6501-9.

MWH. 2015. *Resource Efficiency Programme for the Seychelles Water Sector: Baseline Demand Forecast.* European Investment Bank Contract TA2013030 SC IF2, 139pp.

Narayan S, et al. 2016. *The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences*. PLoS ONE 11(5): e0154735. doi:10.1371/journal.pone.0154735. Retrieved from: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0154735.

NASA. 2016. *Global Climate Change: Vital Signs of the Planet*. http://climate.nasa.gov/vital-signs/sea-level/. - accessed 24 May 2016.

National Bureau of Statistics. 2012. Household Survey 2011.

Nurse, L.A., R.F. McLean, J. Agard, L.P. Briguglio, V. Duvat-Magnan, N. Pelesikoti, E. Tompkins, and A.Webb, 2014. *Small islands*. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1613-1654.

Nygaard, I. and Hansen, U. 2015. *Overcoming Barriers to the Transfer and Diffusion of Climate Technologies*: Second edition. UNEP DTU Partnership, Copenhagen.

Payet, R.A. 2005. *Climate policy implications of the recent ENSO events in a small island context*. In Climate and Africa. Cambridge University Press.

Ragoonaden, S., 2006. *Sea Level Activities and Changes on the Island of the Western Indian Ocean*, Western Indian Ocean Journal of Marine Science 5(2), 179-194.

Ragoonaden, S., Seewoobaduth, J., Cheenacunnan, I. 2015. *Recent acceleration of Sea Level Rise in Mauritius and Rodrigues*. In the Proceedings of the International Colloquium on Climate Change, Mauritius 08-10 October 2015.

Rycerz, A. 2016. *Big engineering and green infrastructure for coastal resilience*. Acclimatise: Building Climate Resilience, April edition.

Seychelles Ministry of Foreign Affairs. 2014. *The Blue Economy – Seychelles Vision for a Blue Horizon*.

Seychelles Meteorological Authority and Météo France La Reunion. 2016. *Unpublished results of down-scaled climate modelling for Seychelles*: Seychelles Meteorological Authority, Seychelles.

Soliman, A. and D. Reeve. 2007. *Artificial Submerged Reefs: A solution for Erosion Problems along Alexandria Coastline, Egypt?* Proceeding of the IMA 2nd Conference on Flood Risk Assessment, Plymouth, UK.

UN (United Nations), 1992. Agenda 21. Available at: http://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (accessed 29 July 2016).

UN. 2014. *Outcome of the Third International Conference on Small Island Developing States. A/CONF.223/3*. Available at: http://www.sids2014.org/index.php?menu=1537 (accessed 14 September 2016).

UNEP. 2011. *A Practical Framework for Planning Pro-Development Climate Policy*: UNEP DTIE, Paris.

Zarine, W.D., Ishikagi, K., Moriniere, L., Egan, C., Mochizuki, J., Hochrainer-Stigler, S.,Mechler, R. and Williges, K. 2015. *UNISDR Working papers on Public Financing Investment and Financing Strategy for Disaster Risk Reduction*: UNISDR, Geneva.

Annex I: The NCCS Action Plan

Action #	Action	Priority
Objective 1 - To advance our understanding of climate change, its impacts and appropriate responses		
Strategy 1.1: Identification of gaps and research priorities required to predict the impacts of climate change in Seychelles		
Action #	**Action**	**Priority**
1.1.1	Assess data needs and important gaps in knowledge that impede adaptation to CC	high
1.1.2	Establish long-term monitoring of oceanographic parameters, including sea level rise and sea surface temperature	high
1.1.3	Consolidate the existing beach and wetland monitoring programmes	moderate
1.1.4	Improve data collection and monitoring for vector distribution on the main inhabited islands, in particular mosquito species	high
1.1.5	Study and prescribe the monitoring/technical requirements required for early warning of extreme storm and wind events	high
1.1.6	Identify climate sensitivity and develop relevant ecological and socio-economic indicators for the artisanal fisheries subsector	high
Strategy 1.2: Development of capacity to manage, analyse and present such data in a manner in which it can be useful for guiding policy and influencing adaptation		
1.2.1	Undertake small and basin-scale modelling using oceanographic monitoring stations and arrays	high
1.2.2	Use high resolution models in the development of CC scenarios for Seychelles	moderate
1.2.3	Assess and research trends and relationships of disease outbreaks or vector distributions within the context of climate variability and change	moderate
1.2.4	Develop health risk plans based upon CC scenarios	moderate
1.2.5	Acquire high resolution DEM data for use in mapping climate-related risks, zoning, and vulnerable areas	high
1.2.6	Incorporate sector data (e.g. agriculture, tourism, fisheries, forestry, etc.) into risk, vulnerability and distribution maps	high
1.2.7	Establish farm-level value at risk database	High
1.2.8	Develop ecosystem modeling for climate-sensitive fisheries	moderate
1.2.9	Model changes in the distribution and productivity of marine resources at a relevant spatial scale under CC scenarios	high
Strategy 1.3: Establishment of sustainable long-term monitoring programmes in strategic areas, with focus on climate scenarios, risk assessments and adaptation		
1.3.1	Access to high-resolution regional and global ocean and coastal datasets	moderate
1.3.2	Establish Sea Level Rise/Tidal Observation stations on other islands of Seychelles	high
1.3.3	Expand rainfall monitoring network for development of appropriate predictive and design tools	high
1.3.4	Establish operational network for monitoring and sharing of data at national & regional level	moderate
1.3.5	Implement mechanisms to ensure sustainability in financing and support of oceanographic research and monitoring	moderate
1.3.6	Implement fisheries-independent monitoring system for coral reef fisheries resources that incorporates resilience indicators	high
Objective 2 - To put in place measures to adapt, build resilience and minimise our vulnerability to the impacts of climate change		
Strategy 2.1: Identify priorities for adaptation, especially in critical sectors		
2.1.1	Study to identify and prioritise areas for adaptation intervention	high
2.1.2	Undertake review of policies and institutions with a view to ensure consideration of adaptation issues	moderate
2.1.3	Evaluate potential coastal risk zones, vulnerabilities and level of protection in place	moderate
2.1.4	Assess the effectiveness of existing adaptation techniques, including impediments to implementation	high
2.1.5	Assess levels of disease/pest control resistance in climate-related vectors	high
2.1.6	Determine adaptation opportunities in fisheries considering socio-economic conditions, fishing pressure, and international trade	high

Strategy 2.2 : Assess and improve ongoing management activities and their contribution to adaptation		
2.2.1	Identify key areas of management which entails consideration of adaptation	high
2.2.2	Development of legally binding coastal land-use plans (incorporating the impact of climate change and natural changes in coastal processes)	moderate
2.2.3	Improvements, awareness and further investments in waste collection and management to reduce flooding and vector/disease propagation risks	low
2.2.4	Improvements to the public health infrastructure in response to climate-driven epidemics improved	moderate
2.2.5	Adoption of coping approaches with regards to the management of protected areas for resilience to climate change	moderate
2.2.6	Establish basic design specifications, incorporating climate change considerations, into coastal drainage, coastal protection, road and other infrastructure development projects	high
2.2.7	Establish and strengthen the role of EIA and SEA in climate change adaptation and risk/impact reduction	high
2.2.8	Develop social and ecological resilience in exploited marine ecosystems through adoption of an ecosystem-approach in fisheries management plans	high
Strategy 2.3 : Implementation of adaptation activities		
2.3.1	Develop and implement on a pilot scale effective adaptation measures and tools at community level, including coastal restoration approaches	high
2.3.2	Research and develop alternative coastal designs (such as elevation of buildings) which accommodate sea level rise	high
2.3.3	Implement nation-wide rainwater harvesting programme	high
2.3.4	Demonstration of adaptation technology implementation, with focus on nature-based methods	moderate
2.3.5	Enhance the management of coral refugia and resilient areas	high
2.3.6	Evaluate and implement new plant varieties, strategies for pest and invasive control for agriculture and forestry, to cope with changed climatic conditions	
2.3.7	Reinforce approaches for sustainability in fisheries through improvements in monitoring and management of fishing zones	very high
2.3.8	Develop and implement cost-effective beach restoration techniques in support of the tourism industry	high
Strategy 2.4: Establish financing mechanisms for adaptation		
2.4.1	Dedicated financing for preventative measures and early warning of climate-related vector disease prevention established	high
2.4.2	Develop the capacity to mobilise and implement resources from international agencies to address the climate risk	high
2.4.3	Explore and develop micro-insurance, risk reduction and financing mechanism and private sector financing options for adaptation	high
2.4.4	Establishment of a National Disaster Crop Insurance scheme	high
Objective 3 - To achieve sustainable energy security through reduction of greenhouse gas emissions		
Strategy 3.1: Diversify the energy portfolio of Seychelles towards renewable forms of energy		
3.1.1	Develop a comprehensive energy policy aimed at charting a strategy to achieve energy security	high & ongoing
3.1.2	Feasibility studies for the establishment of wind, solar and waste-to-energy technologies	moderate
3.1.3	Upgrading of national grid to accommodate alternative sources of energy	moderate
Strategy 3.2: Modernise the energy legislation and institutional framework to encourage innovation and transfer of technology in the energy sector		
3.2.1	Establish legally and strengthen the Seychelles Energy Commission to oversee energy management in Seychelles	high & initiated
3.2.2	Development of new Energy Act	high
3.2.3	Develop and implement framework for enabling financial incentives, including feed-in tariffs, for technology transfer and conservation in the energy sector	high
3.2.4	Implement market-based mechanisms to enhance energy efficiency in industry and other sectors	moderate

3.2.5	Develop appropriate codes and specifications for energy efficiency in the transport, building and commercial sectors	high
3.2.6	Establish a carbon market in Seychelles	moderate
Strategy 3.3: Improve monitoring and assessment of energy use and emissions		
3.3.1	Establish legal requirement for sharing of energy data	high
3.3.2	Develop and maintain energy statistics	high
3.3.3	Maintain data on other sources of GHG emissions as specified in the UNFCCC guidelines	moderate
Strategy 3.4: Technology transfer in the energy production and transport sector		
3.4.1	Establishment of a clearinghouse and advisory services platform on efficient technologies and appliances	high
3.4.2	Establish demonstration projects for various energy technologies with the participation of the private sector	high
3.4.3	Create an enabling environment for the piloting and testing of new vehicle technologies	high
Objective 4 - To mainstream climate change considerations into national policies, strategies and plans		
Strategy 4.1: Addressing institutional learning and stakeholder flows		
4.1.1	Identify and undertake a review of the main institutions involved in responding to climate change, identify conflicts or parallel efforts and explore networking and synergies	high
4.1.2	Review of key procedures, guidelines and specifications to include climate change adaptation considerations into national planning	moderate
4.1.3	Develop programme to raise awareness of the likely impacts of climate change for all identified stakeholders	moderate
Strategy 4.2: Incorporate climate risk assessment and response into Government		
4.2.1	Engagement of government (incl. the executive & legislative) with the scientific community for input of climate risk information into the development of national development strategies, policies and laws	moderate
4.2.2	Identify key stakeholders and develop policy for involvement of key stakeholders in climate change adaptation through a multi-stakeholder coordination committee	high
4.2.3	Update TCPA guidelines and modus operandi to mainstream climate change into key national risk sectors	high
4.2.4	Develop a knowledge platform on mainstreaming adaptation in small islands	high
4.2.5	Revise and implement the Fisheries Policy, Inshore Fisheries Strategy and Fisheries Development Plan to incorporate sector adaptation mechanisms to climate change	high
Strategy 4.3: Incorporate climate risk assessment into the Private Sector		
4.3.1	Development of incentive structures by reducing bureaucracy, barriers to introduction of new technologies and supporting capacity building activities	high
4.3.2	Adoption of guidelines and codes for development which take into consideration climate change issues	moderate
Objective 5 - To build capacity and social empowerment at all levels to adequately respond to climate change		
Strategy 5.1: Develop Climate Change education and communication		
5.1.1	Develop and deploy climate change curriculum and teacher support materials in Seychelles Schools	high
5.1.2	Design and implement climate change educational and advocacy activities	moderate
5.1.3	Integrate climate change education in all relevant national policies and strategies	high
5.1.4	Organize awareness and educational activities for the youth	moderate
5.1.5	Promote ongoing stakeholder/community involvement in decision making regarding climate change education, awareness & training at national and district levels	moderate
5.1.6	Develop capacity for emissions trading and carbon management with focus on CDM, NAMA and other mechanisms	moderate
Strategy 5.2: Implement climate change awareness at all levels		
5.2.1	Identify gaps in communication and implement awareness raising activities within government, private sector and other organizations	moderate
5.2.2	Integrate climate change education into all sectoral policies and strategies, i.e. tourism,	high

	fisheries, energy, agriculture, education, development, disaster response, etc	
5.2.3	Identify vulnerable groups and prioritise for capacity building activities to address climate change risk	high
5.2.4	Develop communication and awareness strategies to engage the community in responding and adapting to climate change	high
5.2.5	Identify the main gender issues in connection with climate change and implement capacity building programmes to address any specific gender-biased needs	moderate
Strategy 5.3: Strengthen formal climate change capacity building institutions		
5.3.1	Introduce climate change research and adaptation training at university level	high
5.3.2	Develop and maintain a knowledge-base and use case studies for climate risk reduction	high
5.3.3	Integrative and adaptation leadership training in "Climate change, climate variability and coastal security"	high
5.3.4	Development of appropriate modes of learning for adaptation at all levels and sectors of society, including aspects of empowerment at the local level	moderate
5.3.5	Establish a system of sustainable financing for climate change education, awareness and training programs	high
Strategy 5.4: Develop the capacity for global environment management, in particular climate change		
5.4.1	Develop capacity for negotiations at international level	high
5.4.2	Develop policy research projects focused on analysis of global policy and mechanisms in relation to the specificities and priorities of small island states	high

Annex II: List of stakeholders involved and their contacts

COASTAL ZONE

Name	Contact details	Affiliation	Approach of consultation	Topics
Selvan Pillay	s.pillay@gov.sc	CAMS DG	Email exchange	Assistance with costing and info about status of projects
P.Murugaiyan	p.murugaiyan@env.gov.sc	CAMS (wetlands)	Interview	Cost of river outlet works
Andre Labiche	a.labiche@env.gov.sc	CAMS (coastal erosion)	Email and participation in MCA workshop	Coastal erosion measures
Hendricks Figaro	h.figaro@env.gov.sc	CAMS (drains)	Email and participation in TWG meeting	Selection of technologies
Jean-Claude Labrosse	j.labrosse@env.gov.sc	CAMS (wetlands)	Email and discussion	Cost of river outlet works
Julie Low	julielow@mluh.gov.sc	MLUH/Planning	Meeting and discussion	Role of planning in coastal protection
Desire Payet	dpayet@slta.sc	SLTA	Email and participation in MCA workshop	Various incl. road damage and costs
Ashton Berry	a.berry@unisey.ac.sc	UNISEY	Email	Soft technologies
Elvina Henriette	elvinahenr@gmail.com	China EBA project	Meeting & discussion	Wetland restoration
. Marc d'Offay	madoffay@gmail.com	civil / coastal engineer	Email, discussion, and participation in TWG meeting	Various, selection of technologies, coral reef augmentation
. Nimhan Senaratne	Nimhan158@gmail.com	civil / coastal engineer	Email and participation in TWG meeting	Various, selection of technologies, status of current projects
. Marcel Belmont	m.belmont@meteo.gov.sc	Seychelles Met. Agency	Email and participation in MCA workshop and TWG meeting	Various including mapping technologies
. Lemmy Payet	lkpayet@hotmail.com	LWMA (DRDM	Email and discussion	Links with DRDM
. Vanessa Zialor	zialorvz@gmail.com	S4S	Email and participation in MCA workshop	Various
. Betty Seraphine	b.seraphine@pcusey.sc	EBA watershed project	Participation in MCA workshop	Various, links with EBA project
. Helena Sims	helena.sims@tnc.org	Iarine Spatial Planning project	Email exchange	Mapping technologies status
. Dave Rowat	dave@mcss.org	ICSS	Email exchange	Mapping technologies and costs
. Nirmal Shah	nirmalshah@natureseychelles.org	ature Seychelles	Discussion	Coral reef technologies and costs

WATER SECTOR

Name	Contact details	Affiliation	Approach of consultation	Topics
Steve Mussard	smussard@puc.sc	Director, Water Section, Public Utility Corporation	Meeting	MCA ,Review selection of technologies, Provide complementary information
Franky Dupres	fdupres@puc.sc	Senior Engineer, Water Section, Public Utility Corporation	Meeting	MCA, Review selection of technologies. provide complementary information
Johan Mendez	j.mendez@pcusey.sc	Hydrologist, Ecosystem based Adaption project	Meeting	MCA Review selection of technologies, provide complementary information
Betty Seraphine	b.seraphine@pcusey.sc	Project Manager Ecosystem based Adaptation project	Workshop	Indicator and criteria
Betty Mondon	b.mondon@pcusey.sc	Community Engagement Specialist, Ecosystem based Adaptation project	Workshop	Indicator and criteria
Michele Martin	martinzanli@gmail.com	CEO, Sustainability for Seychelles	Meeting/ workshop	Indicator and criteria.MCA, provide complementary information
Vanessa Zialor	zialorvz@gmail.com	Project Manager, Sustainability for Seychelles	Workshop	Indicator and criteria

Annex III: Technology Factsheets for selected technologies

COASTAL ZONE

Technology 1: COASTAL RISK MAPPING	
Introduction	Flood hazard or coastal risk mapping is an exercise to define those coastal areas which are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of coastal flooding. However, mapping of erosion risk areas may serve to achieve erosion risk reduction. It acts as an information system to enhance our understanding and awareness of coastal risks.
Technology characteristics	Flood Hazard Mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily-read, rapidly-accessible charts and maps which facilitate the identification of areas at risk of flooding and also helps prioritise mitigation and response efforts (Bapulu & Sinha, 2005). Flood hazard maps are designed to increase awareness of the likelihood of flooding among the public, local authorities and other organisations. They also encourage people living and working in flood-prone areas to find out more about the local flood risk and to take appropriate action (Environment Agency, 2010). Climate change must be carefully considered when implementing flood hazard mapping. Flood hazard mapping typically provides a 'snapshot' of flood risk at a given point in time. When considering the effects of climate change however, it is important to consider the dynamic nature of flood risks. For example, SLR and changes in storm intensity, occurring as a result of climate change, will causes changes in the areas susceptible to flooding. Flood hazard maps can be used by developers to determine if an area is at risk of flooding, and by insurers to determine flood insurance premiums in areas where flood insurance exists. Due to sparse empirical records and the statistical rarity of extreme coastal events, coastal flood prediction often relies on complex numerical models that approximate the processes and phenomena that lead to coastal floods (Water Science and Technology Board, 2009). Coastal flood hazards are determined by the interaction of storm surges and waves with seabed bathymetry and coastal land cover, and extreme hydro meteorological events. These factors determine the inland extent of flooding. Coastal flood models must therefore account for these features, as well as the processes associated with storm surges and waves (Water Science and Technology Board, 2009). The creation of flood maps usually combines topographic data with

	historic or modeled information on extreme sea levels and wave heights. This allows determination of the water level at the coast under extreme conditions and shows how this water could flood inland. This is likely to involve the deployment of storm surge and wave models. The level of protection offered by existing coastal defences should also be accounted for. This helps to determine when overtopping of defences will occur, causing flooding of defended areas. Geographic Information Systems (GIS) are frequently used to produce flood hazard maps. They provide an effective way of assembling information from different maps and digital elevation models (Sanyal & Lu, 2003). Using GIS, the extent of flooding can be calculated by comparing local elevations with extreme water levels.
Costs, including	The costs of coastal risk mapping vary widely depending on the equipment used and the availability of local technical expertise
cost to implement adaptation options	• Bathymetry and Lidar equipment (including maintenance and replacement costs) initial investment 2msr, then SR 150,000 per year x 15= 4.25msr total • Local expertise to undertake bathymetry surveys SR2million per survey, every 3 yrs (x5) Sr 10 million • LIDAR surveys – SR800,000/yr x 15 yrs SR 12msr • Local expertise to process data and produce maps SR 150K per year x 15 yrs = 2.25msr • Training of local experts – SR 1million (2 degrees plus training) • External expertise on numerical modelling of flood risk brought in from academic institutions or commercial organisations 1msr
cost of not implementing the project	Coastal erosion in key high vulnerability areas during times of hydro meteorological extreme events Unforeseen damage to property and roads Possible injury and loss of life during events. Estimated cost per event of damages (from Pointe Larue example SR 100 million, GOS, 2013) – assuming one severe event every 3 years (5 events) total SR 500 million
Potential development impacts, benefits	Coastal risk mapping complements and strengthens other adaptation options, such as flood-proofing measures, emergency planning, provision of flood shelters and evacuation planning. As such, this approach could be applied almost universally, irrespective of the other adaptation technologies that are used.
Economic	Will require investment in some equipment and resources, training and staff to coordinate and manage and external expertise. Maintenance

	and regular monitoring will be critical.
Social	The technology has the benefit of providing maps and information that the public can use to visualize possible flooding scenarios over time.
Environmental	The mapping process itself has minimal impact on the environment. Mapping can be done by aerial photography via drone to minimize carbon footprint.
Status	Some flood hazard mapping has been done in Seychelles, but in specific locations, by different stakeholders. There is a need for more detailed maps, and for a complete map of the coastal zones of at least all of the populated islands.
Barriers	Flood hazard mapping relies on the availability of topographic, and long-term extreme event data and complex numerical modelling techniques. This requires specific modelling capabilities and expertise which may not be readily available in Seychelles. It also requires good coordination and communication among key stakeholders who are producing and using the maps, under the leadership of a central body with the technical capacity. A lack of public understanding about the benefits of flood hazard mapping may also provide a barrier to implementation. If the public is unaware of the benefits of flood hazard mapping, they may prefer to see public money spent on more tangible flood and erosion protection measures.
Acceptability to local stakeholders	Local coastal engineers, DRDM and land use planners recognize the need for flood hazard mapping and are involved in efforts to date. It may not be as obvious to the general public.
Endorsement by experts	Both recent studies involving flood hazard mapping, undertaken by JICA and a team of Cuban researchers, recognized the need for better flood hazard mapping tools and information. The JICA report provides guidelines for taking aerial photos and undertaking bathymetry surveys.
Timeframe	This technology can be implemented immediately but the LIDAR needs to repeated twice per year to track changes, and the bathymetry repeated periodically to track changes around the coast. Some time will be needed to build up local expertise.
Institutional capacity	The Seychelles Coast Guard and the GIS section of the Ministry of Land Use and Habitat, the MEECC and several NGOs have experience with GIS and coastal mapping. At present there is no one person responsible for flood hazard mapping in Seychelles. Also, we would need to invest in training of several people in LIDAR or remote sensing, but could take advantage of simpler technology like drones to undertake the topographic surveys.
Adequacy for current climate	The technology is appropriate for present and future climatic conditions.
Size of beneficiaries group	Large benefits to small number of people involved in decision-making about coastal developments, but to large number of people who will be

	forewarned about flooding risks. Better information available to developers and government when considering proposals for new buildings or other developments in the coastal zone..

Technology 3: Wetland restoration	
Introduction	The primary objective of wetland restoration can be three-fold. These projects can serve to reduce coastal flooding and erosion and can also provide new habitats and environmental benefits. The term 'wetland' refers to a diverse range of shallow water and intertidal habitats, which occur in various locations around the world. Wetland restoration relates to the rehabilitation of previously existing wetland functions from a more impaired to a less impaired or unimpaired state of overall function. Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion management. They induce wave and tidal energy dissipation (Brampton, 1992) and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilise shore sediments, thus reducing erosion (USACE, 1989). Wetland restoration re-establishes these advantageous functions for the benefits of coastal flood and erosion protection. Restoration is required because many of the world's wetlands have become increasingly degraded through both natural and human activities. In Seychelles coastal wetlands include mangrove forests and freshwater marshes.
Technology characteristics	Techniques have been developed to reintroduce coastal wetlands to areas where they previously existed and to areas where they did not, but conditions will allow. The diversity of wetland types means there are numerous methods for restoring wetlands. The method adopted will depend on the habitat which is being restored. For mangrove restoration, it is necessary to collect plant propagules (a structure, such as a cutting, seed or spore that propagates a plant) from a sustainable source, prepare the restoration site for planting and directly plant propagules at regular intervals at an appropriate time of year (de Lacerda, 2002). In re-establishing mangroves, it may also be desirable to establish nurseries to stockpile seedlings for future planting (de Lacerda, 2002). Mangrove re-establishment can also be achieved by planting dune grasses. These grasses provide a stable,

	protective substrate for mangroves to establish their root systems in. However, as the mangroves grow, they will eventually overshadow the dune grasses, causing them to die. Thereafter, the mangrove becomes the dominant species (USACE, 1989). In terms of climate change adaptation in the coastal zone, the main benefit of wetland restoration is the reduction of incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone. This is achieved by increasing the roughness of the surface over which incoming waves and tides travel (Nicholls et al., 2007b). This reduces the erosive power of waves and helps to reduce coastal flood risk by diminishing the height of storm surges. A reduction in installation and maintenance costs of sea defences may occur when such structures are located behind mangroves which absorb the energy and slow the water flow of storm surges (Barbier, 2008). Evidence from the 12 Indian Ocean countries affected by the 2004 tsunami disaster suggested that coastal areas with dense and healthy mangrove forests suffered fewer losses and less damage to property than those areas in which mangroves had been degraded or converted to other land use (Kathiresan & Rajendran, 2005). Observations indicate that a mature mangrove stand will reduce the costs dike maintenance by 25-30% assuming a stand width at least comparable to the characteristic wavelength of incident waves (Tri et al., 1998). In contrast to hard defenses, wetlands are capable of undergoing 'autonomous' adaptation to SLR, through increased accumulation of sediments to allow the elevation of the wetland to keep pace with changes in sea level (Nicholls & Klein, 2005). Provided wetlands are not subjected to coastal squeeze, and the rate of SLR is not too rapid to keep pace, wetlands are capable of adapting to SLR without further investments. Coastal wetlands also provide a number of important ecosystem services including water quality and climate regulation, they are valuable accumulation sites for sediment, contaminants, carbon and nutrients and they also provide vital breeding and nursery ground for a variety of birds, fish, shellfish and mammals. They are also a sustainable source of timber, fuel and fibre (White et al., 2010). The restoration and recreation of wetlands can also reduce or even reverse wetland loss as a result of coastal development. This is important in terms of maintaining the global area of wetlands and in sustaining wetlands in the face of climate change. Wetland creation

	may also fulfil legal obligations for the compensation of habitats lost through development.
Costs, including	• Mapping and modeling costs – SR 50,000/site • Dredging / silt removal or other engineering works like culverts to connect fragmented sites - 2 MSR /site • Purchase of seedlings and plants SR50,000 per site • Replanting works SR 50,000 per site • assuming 10 sites, one site per year x 15 years, each site on average 1ha, total cost of one site 2.2MSR, 10 sites 22MSR • post-implementation monitoring operations – SR 300,000/yr x 15 yrs= 7msr
cost to implement adaptation options	29 MSR
cost of not modifying the project	This is very difficult to estimate given the uncertainties involved in the actual benefits of individual wetland restoration projects. However some guidelines might include: Cost to repair roads/km damaged in floods from blocked wetlands: Cost of dredging and building drains for dysfunctional wetlands: (Cost of clearing drains per m: Cost of repairs to houses damaged by floods: A rough estimate based on damage to the Pointe Larue area (historically a wetland) during flooding event of 2012 is 100MSR. If we have 3 major events involving overflowing and blocked wetlands over the next 15 years up till 2030 the cost could be **300MSR**
Potential development impacts, benefits	The disadvantages of wetland restoration are minimal. The restoration of natural ecosystem services, including flood and erosion protection benefits, largely outweighs any disadvantages. One possible disadvantage is the space requirement in locations which are often of high development potential. This must be carefully weighed against the range of benefits accrued.
Economic	On one hand protecting and restoring (possibly expanding) wetlands may have negative implications for the economy if this land is made unavailable for economic development, such as for the constriction of hotels. The economic benefits of restoring wetlands in terms of protection of the coast and avoided costs are hard to measure, but there may be other indirect economic benefits in terms opportunities for ecotourism.
Social	At present wetlands are only used by the community directly in a limited way (fishing, getting bait, and wood for fish traps – all in mangroves) and are used by many as sites for illegal dumping and littering. There are many opportunities for community engagement through the process of wetland restoration and replanting, and opportunities for schools and the public to learn more about wetland ecology.

Environmental	Protecting wetlands has only positive impacts on the environment, not only providing wildlife habitat, improving water quality and aquifer recharge but also adding in a small measure to greenhouse gas sequestration.
Status	At present there is an EBA project underway that focuses entirely on protection and restoration of coastal wetlands. The project focuses on 10 sites on Mahé and Praslin which were chosen following a study of the status of coastal wetlands. This project involves different activities at different sites but includes: mangrove planting, clean ups, installation of culverts to improve water flow between fragments of a large mangrove, etc. The project funding is limited however, and there may be further actions required and recommended as the initial work is implemented. There are several other initiatives underway – at Port Launay the hotel and community partners are restoring a segment of mangrove that suffered die back during the hotel construction phase, through replanting and corrections to water flow. Numerous community partners (NGO's, community groups, the government) commonly organise clean ups of mangroves and freshwater marshes and mangrove safaris to education the public.
Barriers	Uncertainty and incomplete understanding of the ability of a degraded wetland to recover, and of the success rates of wetland creation is a major barrier to this technology. Uncertainty also surrounds the effectiveness of wetland restoration activities and whether the full range of ecosystem functions will be restored during wetland repair. Monitoring of completed schemes will enhance our understanding of wetland restoration. The adoption of wetland restoration and (re)creation as a response to coastal flooding and erosion requires a sustainability-focused and anticipatory coastal management plan. The establishment of wetlands which provide full coastal flood and erosion protection takes time, and the approach does not offer immediate benefits. As such, wetland recreation may not be practicable where coastal management is reactive and focused on hard defenses. Wetlands only exist under specific conditions and it is not always clear if habitat restoration will be achievable or successful, especially when coastal managers have limited predictive capabilities for shoreline change (NRC, 1994). Although studies have shown that it is possible to create wetlands in areas where they did not previously exist (Platong, 1998), sites with the potential for wetland restoration or creation should be identified on a case-by-case basis. Identifying individuals and organisations qualified to undertake

	wetland restoration and recreation work can also prove a barrier to implementation and directly influence the effective application of scientific knowledge and engineering capabilities and ultimately, project performance. To address problems associated with limitations in knowledge and capabilities, it is advisable to seek technical assistance where needed. In Seychelles one of the most serious barriers is limited land area. Pressure on wetlands and wetland infilling has arisen because of a shortage of land, and already many developments are completed in and around wetlands making full restoration impossible.
Acceptability to local stakeholders	In Seychelles there have been many efforts to educate the public about the importance of wetlands but still there likely remains limited understanding of the actual flood and erosion protection benefits offered by these ecosystems, and the urgent need for wetland restoration. This will hinder the uptake of these projects as communities press for more tangible, hard defense options, for which the protective benefits are more widely understood.
Endorsement by experts	Locally wetland protection and restoration is already recognized by local experts as a key strategy for climate change adaptation and biodiversity conservation. It is also a widely accepted technology internationally.
Timeframe	Wetland restoration takes time to show its full impact. Projects need to start as soon as possible but may take years to reveal the benefits for coastal protection.
Institutional capacity	It is important that the multiple agencies involved in shoreline management avoid providing conflicting guidance. In Seychelles, efforts to reduce flooding of coastal communities have involved clearing and dredging in the mangrove forests at the mouth of some rivers, and mangrove forests are trimmed to avoid interference with electricity lines. Seychelles Wetland Policy (2005) provides a good basis for wetland protection but it has no clout under the law. Past wetland restoration projects in Seychelles have been conducted on an experimental basis through 'learning by doing' with limited technological experience and on a very small scale. Thanks to international funding for a coastal wetland restoration project, more restoration work is already under way. There is a need for good quality detailed maps of coastal wetlands to better plan for their management. At a larger scale, it is useful for governments to adopt proactive and integrated coastal management plans to protect, enhance, restore and create marine habitats, involving multiple stakeholder agencies e.g. in Seychelles, MLUH, SLTA, MEECC. There is a wetland unit in the Climate Adaptation and Management Section of the MEECC, but they are limited in staff and would need additional technical support. Some support is already being provided to CAMS under the EBA China

	project, and to the SNPA through the EBA Coastal project.
Adequacy for current climate	The current climate is conducive to wetland restoration.
Size of beneficiaries group	Wetland restoration will primarily directly benefit the people living in the vicinity of targeted wetlands, who should enjoy better protection from coastal flooding and storm surges. If coupled with an educational approach, wetland restoration could also benefit the tourism industry as it provides opportunities for eco-tour guiding and kayak tours (in the mangroves).

Technology 2: DUNE REHABILITATION	
Introduction	Naturally occurring sand dunes are wind-formed sand deposits representing a store of sediment in the zone just landward of normal high tides (French, 2001). Artificial dunes are engineered structures created to mimic the functioning of natural dunes. Dune rehabilitation refers to the restoration of natural or artificial dunes from a more impaired, to a less impaired or unimpaired state of overall function, in order to gain the greatest coastal protection benefits. Artificial dune construction and dune rehabilitation are technologies aimed at reducing both coastal erosion and flooding in adjacent coastal lowlands. Sand dunes also provide a valuable coastal habitat for many highly specialised plants and animals. As such, sand dunes may be considered important both ecologically and recreationally.
Technology characteristics	Dunes naturally occur along most undeveloped, sandy coastlines. They protect the coast in two ways: they form a barrier between the sea and land, in a similar way to a seawall. Dunes are dynamic and constantly undergoing small adjustments in response to wind, waves and sea level – they can supply sediment to the beach when it is needed in times of erosion, or store it when it is not (French, 2001). There are a number of methods of dune rehabilitation. One such method is to build fences on the seaward side of an existing dune to trap sand and help stabilise any bare sand surfaces (USACE, 2003). This method can also be used to promote dune growth after a structure has been created using bulldozers (Nordstrom & Arens, 1998). Natural materials such as branches or reed stakes are commonly used for fence construction, because they break down once they have accomplished their sand-trapping objective (Nordstrom & Arens, 1998).

	Alternatively, vegetation planting may be used to stabilise natural or artificial dunes. This promotes the accumulation of sand from wind-blown sources around their stems – over time, this causes dune growth. Planting can be achieved by transplanting vegetative units from nursery stocks or nearby intact dunes (USACE, 2003). It can be undertaken at the community level using widely available tools. Over time, dune vegetation root networks also help to stabilise the dune. Dune rehabilitation can also involve limiting human impact along the dunes, by putting bollards in place to limit vehicle access close to the beach, and providing walkways to encourage people to cross the dune at specific sites. Dune rehabilitation is often coupled with sand dredging and beach nourishment, and this may be necessary in Seychelles in the future. Other complementary strategies include revegetating, limiting traffic, and use of timber or rock pilings to encourage sand accretion.
Costs, including	
cost to implement adaptation options	• Timber piling and geotextiles to stabilize dune – SR5,000/m • planting new dunes with vegetation – SR1000/m • Installation of bollards to restrict vehicle access – SR1000/m • Construction of boardwalks for pedestrian access SR50,000 per boardwalk • Construction of alternative parking areas for vehicles – sr 50000 • Public awareness and engagement SR100,000 per site • Each site average 100m – total cost about SR 900,000 • Sand recharge costs average SR 100 / ton (JICA), average 3000t per year x 15= 4.5MSR • One site every year x 15=13.5MSR, w/o sand recharge, including sand recharge **<u>18MSR</u>**
cost of not modifying the project	The loss of beaches will have negative consequences for tourism arrivals to Seychelles. The cost of beach nourishment can be used as a proxy to measure how much it would cost to keep Seychelles beaches looking attractive for tourists. Another cost may be increased damage to roads on or adjacent to the dunes in areas of high risk. Cost estimate based on damage to 100m stretch of road at Mare Anglaise: SR2.5 million x 15 sites = 30 million That doesn't include loss of tourism revenues for degraded beaches – estimate 100msr over 15 years (conservative) TOTAL **<u>130MSR</u>**
Potential development impacts, benefits	Overall, if dune restoration is done using natural methods the benefits outweigh most negative impacts.
Economic	Beaches are a major draw for most of the tourists visiting Seychelles.

	By restoring beaches and dunes naturally, their continued use can be assured.
Social	Beaches on the main granitic islands are used by tourists and locals for picnics and other social activities. Limiting vehicular access to beaches can meet with public resistance but can be mitigated if alternative parking nearby is provided. Dune restoration has many opportunities for community engagement in planting activities.
Environmental	Dune rehabilitation would have positive environmental impacts overall by improving natural habitat in the coastal strip, benefiting wildlife such as turtles, nesting seabirds, etc. Additionally the vegetation used will contribute slightly to greenhouse gas sequestration.
Status	Dunes in Seychelles tend to be very narrow strips of land between the beach and coastal wetlands. Many roads in Seychelles are built right on the dunes, leaving a narrow strip. Government policy is to maintain dune vegetation but in some cases the vegetation has been lost due to coastal erosion or trampling and compaction by vehicle parking near the beach. There have been several projects implemented to revegetate dunes and restrict human activity through placement of bollards and other structures. There have been several attempts to rebuild the dunes through placement of a double layer of timber pilings and geotextiles, and sloped rock armouring, both of which were coupled with planting of native vegetation on the landward side to stabilize the dune. These efforts have met with mixed success and there is a need to further explore the best technologies for dune rehabilitation.
Barriers	Despite being a natural feature of many sandy coastlines, dunes also represent a barrier to beach access. In many cases, dunes have been removed as a result of development and communities have grown used to direct access to beaches and views straight onto the sea. Reconstruction of dunes may receive local opposition if it affects these factors. Land loss is another issue; dunes have a reasonable sized footprint. This space requirement increases further if dunes are to be given sufficient room to adapt to SLR, thus avoiding coastal squeeze. It could be controversial to use land with development potential for dune creation and rehabilitation if the full benefits are not made clear. Alternatively, sand dune construction may take place on an area of beach important for tourism and recreational purposes, therefore restricting its use by the public.
Acceptability to local stakeholders	Not all adaptations technologies will be equally attractive to all stakeholders for political, economic, social, ora cultural reasons Dune restoration might meet with public resistance in areas where people are used to parking their cars or getting direct access to the beach. A well planned public awareness campaign will be essential.
	Dune rehabilitation is an acceptable technology for controlling coastal

Endorsement by experts	erosion and improving wildlife habitat endorsed by the international scientists associated with the TNA process. It is also endorsed by local experts in coastal management and erosion control.
Timeframe	Areas already identified as high risk can be targeted immediately but before implementation can commence, it will take several years to first find suitable dredging sites, and secure equipment needed for on shore recharge of sand.
Institutional capacity	The Coastal Adaptation and Management Section in the MEECC already oversees some dune restoration projects. There is a need for more coastal engineers with expertise in sand movement, and dune restoration methods. On a more basic level there is a need for a simple beach monitoring program and beach sediment tracking system. This information is needed to guide decision making over the short term and long term.
Adequacy for current climate	Because of severe erosion already being experienced in some areas, there is already an urgent need for dune restoration and it is already being done in some cases.
Size of beneficiaries group	This adaptation technology will benefit a very large group including the Seychellois public as well as tourists, all of whom use beach areas, and many Seychellois live around low lying areas that are at risk of flooding.

WATER SECTOR

Technology:	Rooftop Rainwater Harvesting roof top
Technology characteristics	
Introduction	Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. Rainwater harvesting captures, diverts, and stores rainwater for later use. Captured rainwater is often used in landscaping and for secondary uses. Typically**,** independent trials in some countries have shown that a domestic rainwater harvesting system can reduces mains-water consumption by around 50%.Promotion of RWH with household water treatment system could increase climate resilient of households(Ref Technology fact 3)
Technology characteristics/highlights	Commonly used rainwater systems are made up of three principal components; namely, the catchment area, the collection device, and the conveyance system. These systems can range from the low tech, hence low cost to the more advanced technology and thus relatively higher cost.
Institutional and organizational requirements	Though rainwater harvesting can be practiced on an individual basis, it will have to be supported by an institution for it to be successful. There is a need to impart know how as to the implementation and maintenance of the system, and to some extent some financial incentives will be needed. Presently none of the water institution is promoting actively rooftop rainwater harvesting.
Operation and maintenance	Rainwater harvesters are based on simple technologies, and require no special skills. However users will need to become aware of the importance of maintenance and the financial implications this would entail.
Endorsement by experts	Many countries are realizing that in the future surface and groundwater supplies will not be able to meet future water demand. Water conservation and development of alternative water supplies would become a necessity in the near future in order to meet our growing demand for fresh water.
Adequacy for current climate	Seychelles is a tropical country, characterized by wet and dry periods. So rainwater harvesting would serve their purpose well during the wet periods.
Scale/Size of beneficiaries group	Rainwater harvesters can be implemented at residential level, commercial and industrial level. This will alleviate the demand of treated water which is presently used for secondary purposes.
Disadvantages	Retrofitting systems would entail additional costs, as this is not commonly practice in Seychelles.
Capital costs	
Cost to implement adaptation technology	Rainwater harvesters based on concrete storage tanks would be costing some SR. 15,000-25,000 per unit including installation costs depending of the size of rainwater tank require. It is as well proposed to include into the rainwater system a water treatment system that would cost around 2000sr per household In Seychelles there are 28,367 households. So if each households would equipped with one system of rainwater harvesting it will costs around 616 million Seychelles rupees on a basis' of a total average cost per household of 22000 SR

Technology:	**Rooftop Rainwater Harvesting roof top**
Additional cost to implement adaptation technology, compared to "business as usual"	Maintenance cost was estimated SR. 200-500 per year. The system will have to be updated every 5 years.
Development impacts, direct and indirect benefits	
Direct benefits	Reduction in demand of treated water, reduction in wastage and more efficient use of treated water.
Reduction of vulnerability to climate change, indirect	No negative impacts associated.
Economic benefits, indirect Employment Growth & Investment	 There will be a need for trainers who will be responsible to provide the know how to resident. This will open avenue for small scaled enterprises that would be concerned with the developing rainwater harvesting system as per the requirement of the residents.
Social benefits, indirect Income Education Health	 Additional water can encourage back yard farming/gardening Awareness will be raised as to the need of adopting conservation water measures. Reduction of health risks to those who do not have access to water on a regular basis especially during dry periods.
Environmental benefits, indirect	Reduction in water losses/wastage.
Local context	
Opportunities and Barriers	Since rainwater harvesting is not commonly practiced yet, there will be a need to retrofit systems, and this may be looked upon as a deterrent. Opportunities are high, both in terms of creativity to come up with rainwater harvesters which will merge in the environment to the implementation of such systems at national level.
Market potential	Rainwater harvesting is not a new technology, but what will be of market value are systems which are robust and durable to withstand tropical climates. Such systems will have sound market potential both in Seychelles and in other similar countries.
Status	This technology is currently implemented on a very low level. Three local shops have supplying rainwater storage tanks (aquaglass, souris, city enterprise). Three main suppliers of plumping fixtures could install rooftop rainwater harvesting system(Bodgo, Bestway, Watermaster)
Timeframe	Short Term – as it all the requirements are readily available on the local market.
Acceptability to local stakeholders	It is already readily accepted as resident most year are experiencing water restriction even though 95% inhabitants are connected to tap water.

Technology:	Water efficient fixtures and appliances
Technology characteristics	
Introduction	Water use per capita increase with the economic development and the use of water efficient appliances in homes, institutions and businesses can contribute greatly to water conservation efforts.
Technology characteristics/highlights	The most common water efficient appliances include dishwashers and clothes washing machine, toilets, showerheads and faucets. These technologies can be more complex using grey water from the sink for toilet flushing. 3 strategies to increase the use of water efficient appliances: Mandates: mandating water efficient standards Labeling/ certification of water efficient products Tax incentives The combine use of water efficient technologies at household could reduce water by 30-40%
Institutional and organizational requirements	The diffusion of these technologies will require an authority to set up the standard, test and certify. It will require as well an information campaign and most likely tax incentives to do so
Operation and maintenance	n/a
Adequacy for current climate	Will be easy to scale as there is already incentives existing most for energy efficiency and renewable energy technologies
Size of beneficiaries group	The whole population
Disadvantages	There is risk to have a misrepresentation and corruption of the labeling system
Capital costs	
Cost to implement adaptation options	There is already the Seychelles bureau of standard and it could most probably be integrated into the work. Costs for household are generally small and may be fully recovered by water savings over the lifetime of the products.

Device	Availability	Min. Price (SCR)	Max. price (SCR)
Dual flush toilet	10 shops	1,500.00	5,000.00
Dual flush toilet (fittings)	6 shops	140.00	498.00
Low flow shower head	3 shops	85.00	106.00
Adjustable flow shower head	5 shops	130.00	373.00
Concussion taps (self-closing)	6 shops	315.00	640.00
Taps with aerators	4 shops	150.00	950.00
Aerator fitting for taps	2 shops	10.00	12.00
Washing machine	1 shops	4,500.00	5,500.00

Additional cost to implement adaptation option, compared to “business as usual” (extra	

Technology:	Water efficient fixtures and appliances
storage capacity)	
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Water conservation is an important climate adaptation strategy to reduce pressure on existing water resources.
Economic benefits Employment Investment	Water conservation can lead to energy saving used to transport, treat and distribute pipe water and as well contribute to reduce use of desalination plant which require a lot of energy to operate. It will create opportunities for businesses to sell water efficient appliances
Social benefits Income Learning Health	 Water savings made by household will increase income available to household Increase and continue access to water will lead to large health gain
Environmental benefits	
Local context	
Opportunities and Barriers	It will require an innovative information campaign on water conservation issues. Appliances are not often available on the market. Processus for adoption of standards are often slow
Market potential	Important potential market as most of the household are not yet equipped with such appliances
Status	Water efficient technologies are available on the local market(dual flush toilet system, low showerhead and taps)
Timeframe	medium
Acceptability to local stakeholders	Low due to lack of information and awareness on water conservation by households

Technology:	Ground Surface Rainwater Harvesting
Technology characteristics	
Introduction	Most precipitation that falls in the Seychelles run off into rivers and ends up into the sea. small-scale collection infrastructure can contribute greatly to the volume of freshwater available for human use mostly in the agriculture/livestock sector and landscaping
Technology characteristics/highlights	There are two main categories of technologies: • Collecting rainfall from ground surfaces utilizing “micro-catchments” to divert or slow runoff • Collecting flows from a river, stream or other natural watercourse The most commonly used technology in the Seychelles are small reservoirs with earthen bunds or embankments to contain runoff or river flow strengthened with gabions
Institutional and organizational requirements	Policies, legislation and institutional capacity are needed to address conflicts and externalities that can result from to rainwater collection. Conflicts between small-scale farmers competing for limited runoff and the Public Utilities Corporation can happen. Rainwater collection projects can have adverse hydrological impacts on communities downstream

Technology:	Ground Surface Rainwater Harvesting
	if too much water is stored or diverted. Local governments must have the technical ability to assess these impacts if they are to prevent major externalities and resolve conflicts. Knowledge of geographic information systems (GIS) and remote sensing/satellite imagery software and other tools are necessary to determine small reservoir storage capacity.224
Operation and maintenance	Minimum maintenance is requirement once the system is established
Adequacy for current climate	It will help to maximize the use of the runoff water
Size of beneficiaries group	Farmers community
Disadvantages	Rainwater collection projects can have adverse hydrological impacts on communities downstream if too much water is stored or diverted. The authority must have the technical ability to assess these impacts if they are to prevent major externalities and resolve conflicts
Capital costs	
Cost to implement adaptation options	It is estimated that the total cost per year for systems with gabion of a total length of 45 meter long is 420000SR.The size of such system could collect around 96000m^3/year
Additional cost to implement adaptation option, compared to “business as usual” (extra storage capacity)	Maintenance costs are estimated at 120,000 SR per year.
Development impacts, indirect benefits	
Reduction of vulnerability to climate change, indirect	Lack of adequate water supply during drought and seasonal dry periods can halt economic development and have an important impact especially in the agricultural sector .This technology will help the agricultural sector have to a constant and regular water supply for agricultural production
Economic benefits	Increasing the availability of irrigation water during the dry season and even during short dry spells has been shown to yield large increases in agricultural production
Social benefits Income Learning Health	It will help the farmers community during dry season
Environmental benefits	It will contribute by having the soil moist to have a more resilient ecosystem to climate change
Local context	
Market potential	300-400 farmers
Status	Limited use
Timeframe	Short term
Acceptability to local stakeholders	High

Annex IV: MCA calculators

COASTAL ZONE

Please see Excel file named “MCA – Coastal Zones – TNA Seychelles.xlsx”.

WATER SECTOR

Please see Excel file named “MCA – Water Sector – TNA Seychelles.xlsx”.