REPUBLIC OF LIBERIA

COASTAL ZONE'S TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

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Foreword

In September 2015, Liberia, as a signatory of the UN Climate Change Convention, submitted the Nationally Determined Contribution (INDC) in advance of the new climate change agreement reached at the UN Climate Conference in Paris in December. Liberia's INDC was designed as a platform to integrate its Low Carbon Development Strategy into the country's long-term sustainable development vision by 2030 (Agenda for Transformation). Liberia ratified the Paris Agreement in August 2018 and is working hard to revise its NDC for submission. Regardless of the many contributions to climate change, Liberia, like many other developing countries, is especially vulnerable to its impacts. The country is at this moment susceptible to the adverse effects of climate change such as shifting cultivation in the agriculture sector, unsustainable logging practices, unregulated coastal mining, high level of biomass consumption in the form of charcoal and fire wood for local energy use, and decreasing river flow due to high level of evaporation. The agricultural sector, which ensures the livelihoods of around 70% of the population, remains vulnerable to flooding and erosion with changing rainfall patterns putting lives at risk in a country where nearly 8 out of 10 people do not have secure access to food. Current climate change vulnerability in Liberia include; increase in extreme events (e.g., exacerbated floods, extreme drought), sea level rise, flooding and coastal erosion being experienced on an annual basis that eats up the coast as observed in Monrovia, Buchanan and Greenville.

I would like to add that Liberia has an overall lack of energy. In most rural areas in Liberia, less than 5% of the population has access to electricity while most homes run mini generators. The current energy situation in Liberia is characterized by a dominance of traditional biomass consumption, low access to poor quality and relatively expensive modern energy services. It is estimated that over 95% of the population rely on firewood, charcoal, and palm oil for their energy needs.

The EPA of Liberia is overly happy with the level of the assessment done by the Technology Needs Assessment Team (TNA) through a national stakeholder's participatory process emulating from the identification and prioritization of environmentally sound technologies to the diffusion of these technologies to mitigate and adapt to climate change. We would like to recognize the United Nations Environment Programme (UNEP), DTU Partnership and Global Environment Facility (GEF). Your contributions have resulted in this rich source of information and we hope that this report will spur parties into seeking out partnerships for the purpose of accelerating climate action and increasing ambition in Liberia.

Dr. Nathaniel T. Blama Sr.
EXECUTIVE DIRECTOR/CEO

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List of Acronyms and Abbreviations

AfT	Agenda for Transformation
BAEF	Barrier Analysis and Enabling Framework
CAP	Coastal Add-On Project
CSO	Civil Society Organization
DNA	Designated National Authority
DTIE	Division of Technology, Industry and Economics
EPA	Environmental Protection Agency
ERC	Energy Research Centre
EST	Environmentally Sound Technology
EVD	Ebola Virus Disease
FDA	Forestry Development Authority
FWS	Flood early Warning System
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	"Deutsche Gesellschaft für Internationale Zusammenarbeit", (German Society for International Cooperation)
GOL	Government of Liberia
ICZMU	Integrated Coastal Zone Management Unite
INC	Initial National Communication
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
LISGIS	Liberia Institute for Statistics and Geo-Information Services
LULUCF	Land Use, Land-Use Change and Forestry
MCA	Multi-Criteria Analysis
MGCSP	Ministry of Gender, Children and Social Protection
MME	Ministry of Mines and Energy
MoA	Minister of Agriculture
MoF	Minister of Finance
MoPEA	Minister of Planning and Economic Affairs
MoT	Ministry of Transport
MSWG	Mitigation Sectorial Working Group
NAPA	National Adaptation Programme of Action

NCCS	National Climate Change Secretariat
NCCSC	National Climate Change Steering Committee
NDMA	National Disaster Management Agency
NDMP	National Disaster Management Policy
NGOs	Non-government organizations
NPRSCC	National Policy and Response Strategy on Climate Change
PAPD	Pro-Poor Agenda for Prosperity and Development
PRS	Poverty Reduction Strategy
RREA	Rural Renewable Agency of Liberia
SDGs	Sustainable Development Goals
SWGs	Sectoral Working Groups
TAP	Technology Action Plans
TFS	Technology factsheets
TNA	Technology Needs Assessment
TWG	Technical Working Group
UDP	United Nations Environment Programme and Technical University of Denmark Partnership
UL	University of Liberia
UNEP	United Nations Environment Programme
UNEP-DTU	United Nations Environment Programme and Technical University of Denmark
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

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Acknowledgement

This coastal zone's Technology Needs Assessment for climate change adaptation in Liberia has been achieved through a tremendous collaborative effort by many institutions, affected and vulnerable coastal communities through stakeholders' engagements, sites' visits, documents and interviews with residents of coastal communities facilitated by the Environmental Protection Agency of Liberia (EPA) and the TNA. The institutions, communities and individuals mentioned in this report are duly acknowledged for their valuable contributions that successfully resulted to this report.

We would like to express our sincere appreciation to the national Technology Needs Assessment (TNA) team headed by its national coordinator *Mr. Christopher B. Kabah* and also in particular, *Mr. Benjamin S. Karmorh* of the Environmental Protection Agency of Liberia (EPA) climate change department and specifically the Executive Director / CEO of the EPA, *Dr. Nathaniel T. Blama, Sr.* for their support and commitment to this process. Our heartfelt gratitude goes to the coastal zone technical working group *(Annex II)* for their tireless efforts and contributions to this report.

The development of this document was made possible largely due to the generous financial support received from the Global Environmental Facility (GEF) through the United Nations Environment Programme (UNEP) and the Technical University of Denmark (DTU), UNEP-DTU partnership that provided technical and methodological support in conducting the TNA process. Their support to this project that has produced this report, has built the necessary momentum for a national paradigm shift in our understanding of the current threats of coastal risks and vulnerabilities along the nation's coastline that urgently require some adaptive and mitigative approach.

Report I
TNA Report

Executive Summary

The coastal zone is one of the nation's greatest environmental and economic assets. In Liberia, more than 70% of the population lives within its coastal areas which cover approximately 580km in length, (DAI 2008). However, the direct impacts of coastal erosion and floods have become some of the alarming climate change risks currently affecting coastal cities and communities along majority of Liberia’s coastline. Currently, lives and properties, including socio-economic activities, coastal habitats and ecosystems along the nation’s coastline are faced with the direct threats from coastal erosion, flood and related sea level rise impacts. The impact of coastal erosion is currently disrupting livelihoods, destroying properties and leaving many residents homeless in coastal communities due to the lack of sustainable approach to mitigate or adapt to the direct threats presented to the communities.

Therefore, the Technology Needs Assessment (TNA) for climate change adaptation in Liberia has been a set of activities to identify and determine the adaptation technology priorities of the country. TNAs are central to the work of the Parties to the Convention (Article 4.5 UNFCCC). The TNA will lead to the development of a national Technology Action Plan (TAP) that prioritizes technologies, recommends an enabling framework for the diffusion of these technologies, and facilitates identification of suitable technology transfer projects and their links to relevant financing sources in order to have the prioritized technologies adopted within the country’s most vulnerable areas to the above climate change impacts.

Liberia’s TNA project has been led by the Environmental Protection Agency (EPA) and has covered two areas: Mitigation (Energy) and Adaptation (Coastal zone and Agriculture). The technology needs assessment on adaptation is being undertaken in Liberia for the first time. However, Liberia conducted vulnerability assessments and identified priority adaptation sectors and activities in the First National Communication (INC) and the National Adaptation Program of Action in 2008 (NAPA, 2008). The TNA for adaptation is an opportunity to determine the highest priority sectors and technologies for adaptation in the country. This

report focuses on the identification and prioritization of adaptation technologies for the coastal zone to reduce climate change risks and the level of vulnerability to lives and properties. Liberia is a developing country with a small population with vast majority of its population living in poverty. In recent years, climate change related challenges have become a major risk for the country's development. Ecosystems within the country are fragile to climate change and weather, and the environment which directly affect livelihoods of people. Climate change and vulnerability assessments have demonstrated that climate change will affect the well-being of people and the country's socio and economic development.

The Liberian government has passed several important policies and law for long-term sustainable development and climate change. Policies and development strategies developed have clearly stated the importance of adaptation of major sectors such as agriculture and the coastal zone to climate change and include objectives to cope with climate change related risks.

The following major steps have been followed in the assessment:

- An organizational structure has been established and stakeholders engagements facilitated;
- Implications of climate change for the country's development priorities and strategies have been defined;
- Sectors and subsectors have been prioritized;
- Technologies have been identified as high priorities for climate change adaptation.

The TNA process was participatory, which ensured the involvement of cross-sectorial experts and stakeholders in sectors and technology prioritization. Consequently, stakeholder engagement was one of the key aspects of the process. Different entities including ministries and agencies, research and educational institutions, international and national NGOs, private enterprises, and representatives of farmers were involved in the process in different ways.

Based on the research and Multi Criteria Decisions Analysis (MCDA), Agriculture, Coastal zone and Energy sectors were identified as the sectors that are most vulnerable to climate change and their social, economic and environmental losses are expected to be higher than those of other sectors. The coastal zone sector is a major economic sector in Liberia. Said sector provides a means of livelihoods / income for majority of the people, as more than 70% of Liberia's population lives within its coastal areas of about 580km long (DAI 2008).

Therefore protecting these areas from climate change direct threats is vital to the nation's economic and developmental agenda.

In order to protect Liberia's coastal sector, three (3) technology options were selected / retained by the coastal zone Technical Working Group (TWG) headed by the national coastal consultant *"E.Tenesee Wilson"*. The selection of the three technologies from others was based on the technology's potential to reduce vulnerability to climate change and social, economic, and environmental benefits using the TNA "*Multi Criteria Analysis (MCA)"*. The MCA provides a structured framework for comparing a number of technologies against multiple criteria. The prioritized three technologies and brief descriptions to be used for the TNA project in the coastal zone of Liberia are:

1. Integrated Coastal Zone Management (ICZM):

The ICZM is a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. The ICZM seeks over the long-term to balance environment, socio-economic, cultural and recreational objectives all within the limits set by natural dynamics. It covers the full cycle of information collection, planning, decision making, management and monitoring of implementation in the coastal zone.

2. Flood early Warning System (FWS):

In general, the FWS aims to reduce the degree of casualty that could be caused by coastal flooding through alerting the public in advance to take appropriate actions (Response). It detects threatening events in advance to help protect lives and properties in coastal areas.

3. Armour or Rocks Revetment.

The armour or rocks revetment is a type of coastal defence that protects against erosion caused by wave action, storm surge and tidal effects. It protects and fixe the boundary between the sea and land; these actions protect and assist in maintaining the landward environment. Rocks revetments also minimize the destructive and hazardous risks to coastal ecosystem, vegetation, sand dunes and important infrastructures.

Chapter 1: Introduction

1.1 About the TNA project

Climate change and its accompanying impacts of degradation of terrestrial biological systems are some of the most daunting environmental problems in the world; posing socio economic, technical and environmental challenges. Liberia is no exception to climate change challenges and it is currently faced with some extreme weather events, which severely affect food security; as traditional farming seasonal practices become unpredictable while sea level rise and coastal erosion are affecting infrastructure and the livelihoods of coastal communities. According to Liberia's Intended Nationally Determined Contributions (INDC, 2010), vulnerability and adaptation assessments conducted have revealed that Liberia is faced with climate change variability leading to extreme events. These events have a negative impact on agriculture, coastal zone, forestry, health, energy and other sectors. Climate change impacts are marked by irregular patterns of rainfall, flooding, high temperature, and coastal erosion (INDC, 2010).

Climate change has noticeably and adversely affected natural resources, agriculture, the natural environment and other socio-economic sectors in Liberia. Consequently, the vulnerability of the country to climate change needs to be reduced to ensure sustainable development. This will require adaptation and mitigation measures in order to increase the country's resilience in areas like: health and social systems; agriculture; biodiversity and ecosystems; production systems and physical infrastructure, including even the energy grid. Within this overall development and climate policy context, a key step is to select technologies that will enable the country to achieve social equity and environmental sustainability, and to follow a low emissions and low vulnerability development path (Technology Needs Assessment for Climate Change, 2010).

Technology Needs Assessments (TNAs) are a set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of a country. TNAs are central to the work of the Parties to the Convention (Article. 4.5 UNFCCC). They present a unique opportunity for countries to track their needs for new equipment, techniques, services, capacities and skills necessary to mitigate GHG emissions and reduce the vulnerability of sectors and livelihoods to climate change.

TNA development is a key component of the Poznan Strategic Programme on Technology Transfer supported by the Global Environmental Facility (GEF). United Nations Environment Programme (UNEP), on behalf of the GEF, is implementing a new round of TNAs with objectives that go beyond identifying technology needs. The TNAs will lead to the development of a national Technology Action Plan (TAP) that prioritizes technologies, recommends an enabling framework for the diffusion of these technologies and facilitates identification of good technology transfer projects and their links to relevant financing sources. The TAP will systematically design practical actions necessary to reduce or remove policy, financial and technological related barriers. UNEP Division of Technology, Industry and Economics (DTIE) in collaboration with the UNEP Risoe Centre provide targeted financial, technical and methodological support to assist countries in conducting TNA projects.

The Liberia TNA project is led by the Environmental Protection Agency (EPA) and covers the two areas of mitigation and adaptation. Liberia is currently participating in the TNA process for the first time. It has identified its key sectors with priority to climate change threats and impacts. This work covers the prioritized technologies and procedure followed for the coastal zone. However, Liberia has conducted a vulnerability assessment and identified priority adaptation sectors and activities in the Intended Nationally Determined Contributions (INDC), and National Policy and Response strategy on Climate change (NPRSCC, 2018). Moreover, The Agenda for Transformation (AfT, 2013), the country's national development document, recognizes climate change adaptation and mitigation under Pillar V as a cross cutting issue.

The TNA for adaptation has given Liberia an opportunity to determine the highest priority sectors and technologies for adaptation. In addition, the project gave methodological and capacity building support to the country team to enable them to identify the most suitable technologies for effective climate change adaptation and vulnerability reduction.

At the end of the Project, the outcomes of the Technology Needs Assessment, Barrier Analysis, Technology Needs Assessment for Climate Change Adaptation in Liberia Action Plan and Enabling Frameworks will provide background to accelerate the development and transfer of the priority technologies in the country.

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

Liberia is a developing country, located within sub-Saharan Africa with a small population and high rated endowment in natural resources including minerals and forest resources. The country suffered from a 14-year civil crisis that destroyed its infrastructures and socio-political systems.

In recent years, climate change related challenges have become some of the main risks for the country's development. Ecosystems of the country are fragile to climatic changes and livelihoods of the people depend on the weather and environment. Climate change impact assessments have demonstrated that climate change will, and is currently affecting the well-being of people and socio-economic aspects of the country (USAID, 2013). There is environmental degradation with a gradual loss of forest cover and the impact of climate change is already being felt in variability of climactic conditions with uncertain rainfall, increasing temperatures and sea erosion (noticeably in coastal communities). The government of Liberia has passed several important policies and strategic documents of long-term sustainable development to combat climate changes.

The main policies and strategies of development have clearly stated the importance of adaptation of major sectors. Below is the list of some policies, laws and projects to combat climate change:

Table 1: Some major development strategies, policies and projects of Liberia related to climate change Adaptation

Policy	Description and relation to climate change adaptation
The Agenda for Transformation (AfT), 2013	The country's national development document recognizes climate change adaptation and mitigation under Pillar V as across cutting issue. **AfT (2013),** *Agenda for Transformation, Republic of Liberia*, The Governance Commission of the Republic of Liberia, viewed 4 June 2019.
National Policy and Response Strategy on Climate Change (NPRSCC), 2018	The climate change policy and strategy document is prepared in order to ensure that climate change adaptation and mitigation issues are mainstreamed at policy level and in key sectorial and cross-sectorial development efforts. The NPRSCC includes concrete policy and measures in specific areas on climate change adaption and mitigation, action and resource mobilization plans and monitoring and evaluation framework. **NPRSCC (2018),** *National Policy and Response strategy on Climate change-Liberia*, NUDRR PreventionWeb, viewed 5 June 2019.

Coastal Add-On project (CAP)	Government of Liberia obtained funding from the Global Environmental Facility (GEF) through the UNDP to Enhance Resilience of Liberia's Montserrado County Vulnerable Coastal Areas to Climate Change Risks. The CAP constructed a 1200 (One Thousand, Two Hundred) linear metres coastal defence "Revetment" in the D-Twe, Kru-Town area to reduce the vulnerability of the community's population and natural coastal environment to climate change risks, and enhance the capacity of the community to recover from coastal erosion impacts. **Republic of Liberia Ministry of Mines & Energy 2018,** *Coastal Add-On project (CAP) Coastal Defence*, Republic of Liberia Ministry of Mines & Energy, viewed 2 April 2019.
National Environmental Policy of Liberia, 2003	The overall goal of the national environment policy is to ensure long-term economic prosperity of Liberia through sustainable social and economic development, which enhances environmental quality and resource productivity on a long-term basis that meets the requirements of the present generation without endangering the potential of future generations to meet their own needs. **NEP (2003),** *National Environmental Policy*, EPA Republic of Liberia, viewed 8 May 2019.
National Disaster Management Policy of Liberia, 2012	The National Disaster Management Policy provides an overall framework for disaster management in Liberia. The NDMP compliments other national plans, policies and legislations related to drought and climate change management and it provides a platform for the harmonization of all disaster risks management strategies/policies in Liberia. It particularly aims at integrating risk reduction as appropriate into development policies and planning at all levels of government, including the environment, land, agriculture & forestry sectors, coastal areas and etc. **National Disaster Management Agency 2012,** *National Disaster Management Policy (NDMP) of Liberia*, PreventionWeb, viewed 2 September 2019.
National Adaptation Programme of Action (NAPA) 2008 - Liberia.	The Liberia's National Adaptation Program of Actions (NAPA) provides measures to cope with the urgent and immediate needs associated with the increasing climatic volatility and future climate change. NAPA prioritizes three sectors for adaptation: **Agriculture-** Enhancing resilience to increasing rainfall variability through the diversification of crop cultivation and small ruminants rearing; -Building of a national **hydro-meteorological monitoring system** and improved networking for the measurement of climatic parameters; and -Building of **coastal defence systems** to reduce the vulnerability of urban coastal areas. The NAPA further recognizes long-term adaptation initiatives, which will include fisheries, health, and transport; all with an integrated gender-responsive approach to ensure progress toward efficient and effective adaptive capacity and resilience. **NAPA. (2008).** *National Adaptation Program of Action- Republic of Liberia,* UNDP

	Liberia.
Intended Nationally Determined Contributions (INDC) 2010, Liberia	The INDC (2010) shows that Liberia recognizes the current and future threats of climate change. The document provides some efforts and initiatives that have been undertaking by Liberia towards addressing climate change threats. Liberia's INDC presents a platform to integrate its Low Carbon Development Strategy into the country's long-term sustainable development Vision by 2030 (Agenda for Transformation). The INDC includes one component on mitigation and one on adaptation. **INDC EPA Liberia (2010).** *Intended Nationally Determined Contributions of Liberia*, UNFCCC INDC, viewed 2 April 2019.

1.3 Vulnerability assessments in the country

The Intergovernmental Panel on Climate Change (IPCC) defines climate change vulnerability in its third assessment report as *"the degree, to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity, and its adaptive capacity"* (IPCC, 2001). In Liberia, a climate change assessment (USAID, 2013); and vulnerability and adaptation assessments (INDC, 2010) conducted revealed that Liberia is faced with climate change and variability leading to extreme events, which have negative impact on agriculture, forestry, health, energy, coastal zone and other sectors. Climate change impacts are marked by irregular patterns of rainfall, flooding, high temperature, and coastal erosion.

Liberia has an about 580-km long coastline. An estimated 95 km^2 of land along the coast of Liberia would be inundated if sea level rises 1 m (DAI, 2008). Under a scenario of a 1-m rise in sea level, about 50% (48 km^2) of the total land loss due to inundation will be the sheltered coast. For example, parts of the capital city of Monrovia, West Point, New Kru-Town, River Cess, Buchanan, Greenville, and Robert Sport will be lost because much of those areas are <1 m above mean sea level (USAID, 2013 ; DAI, 2008). Likewise seaward portions of the remaining mangrove wetlands will be lost. About $250 million worth of land and infrastructure will also be lost. Others using various global climate models project a sea-level rise in Liberia of 0.13-0.56 m by the 2090s relative to the sea level from 1980-1999 (McSweeney et al. 2010). The evidence of climate change is visible in Liberia, affecting both the environment and the socio-economic structures of the ordinary people. The choice for adaptation underscores the urgent need to put measures and strategies in place for countering the already manifest effects of climate change in the country. Considering recommendations from the vulnerability and climate change assessment, the Liberia's National Adaptation Program of Actions or NAPA prioritizes three sectors for adaptation:

1. ***Agriculture-*** Enhancing resilience to increasing rainfall variability through the diversification of crop cultivation and small ruminants rearing;
2. Building of a national ***hydro-meteorological monitoring system*** and improved networking for the measurement of climatic parameters; and
3. ***Building of coastal defense systems*** to reduce the vulnerability of urban coastal areas.

The NAPA further recognizes long-term adaptation initiatives, which will include fisheries, health, and transport; all with an integrated gender-responsive approach to ensure progress toward efficient and effective adaptive capacity and resilience.

1.4 Sector selection

Climate change vulnerability and adaptation assessments conducted in Liberia revealed that Liberia is faced with climate change and variability leading to extreme events, which have negative impacts on agriculture, forestry, health, energy, coastal zone and other sectors. Among key vulnerabilities to climate change are extreme weather events, which severely affect food security, as traditional farming seasonal practices become unpredictable, while sea level rises, coastal erosion and floods are affecting infrastructure and the livelihoods of coastal communities.

Considering Liberia's climate change vulnerability and Liberia's NAPA, the Technology Needs Assessment project in the country has prioritized three major areas considered to be highly vulnerable to climate change impacts for adequate intervention of adaptation and mitigation.

The TNA process in Liberia is headed by the Environmental Protection Agency (EPA); as such, the selection of the sectors for technology prioritization was conducted in consultation with multiple stakeholders, government ministries and agencies, non-governmental organizations (NGOs), private sectors, research groups, representatives of traditional farmers and etc. Considering the recommendations from some of the mentioned climate change vulnerability assessments of Liberia, the TNA national coordinator alongside the above mentioned stakeholders have selected the three sectors listed below, as priority for urgent adaptation and mitigation measures due to prevailing climate change impacts affecting livelihoods and the natural environment.

- **Adaptation:** Coastal zone sector and Agriculture sector;
- **Mitigation:** Energy sector

These sectors were selected using some of the below conditions:

- Most vulnerable to the impacts of climate change ;
- Current mitigation and adaptation needs;
- Sectors for mitigation should be those that account for most of the national GHG emissions;
- Sector should have Socio-economic importance;
- Government support in technology rollout.

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

Climate change as defined by the United Nations Framework Convention on Climate Change (UNFCCC, 2004), *"is a change of climate which is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".* The evidence of climate change in Liberia is well expressed in climate variability leading to extreme events, which have negative impact on agriculture, forestry, health, energy, coastal zone and other sectors. Climate change impacts are marked by irregular patterns of rainfall, flooding, high temperature, coastal erosion, seawater /saline intrusion into fresh drinking water in coastal communities.

A national response to climate is to address adaptation to climate change, which is an important policy goal for Liberia. The choice for adaptation underscores the urgent need to put measures and strategies in place for countering the already manifest effects of climate change in the country.
According to Liberia's National Adaptation Program of Actions (NAPA, 2008), agriculture, coastal zone and energy are the major sectors that are highly vulnerable to climate change threats.

As climate change impacts are marked by irregular patterns of rainfall, flooding, high temperature, and coastal erosion; these factors result in crops and livestock losses that intensify food insecurity and loss of income. For the most part, women and children are particularly affected and vulnerable to the impacts of climate change in Liberia. However, their unique knowledge and perspectives also provide opportunities for inclusive, equitable and efficient adaptation responses and coping strategies. The limited supporting infrastructures increase the level of vulnerability of the population. Coastal areas in Liberia are the most populated and economically vibrant. Sea /coastal erosion continue to pose increasing threats to the shorelines of coastal cities including major infrastructures and investments. It can also lead to displacement, loss of lives and properties and can severely undermine national security and development.

Coastal erosion has been severe in Monrovia, Buchanan, and Greenville. During 1981 to 1997, about 100 m of beaches have reportedly been lost (EPA 2007). DAI (2008) reported current beach erosion rates are as high as 3 m/yr with ongoing structural damage and loss. According to USAID (2013), the underlying rates of erosion are likely primarily related to natural conditions (e.g., geology, longshore currents, wave action), but recent human interventions (e.g., uncontrolled sand mining, vegetation destruction, dams, poorly placed breakwaters and ports, groynes, or gabions,) also likely have accelerated or directly caused coastal erosion in all these areas. It is projected that about 95 km^2 of land in the coastal zone of Liberia will be inundated as a result of one-meter sea level rise, with about 50% (48 km^2) of the total land loss due to inundation being the sheltered coast (Wiles, 2005).

Rainfall and Temperature

Liberia has two major seasons; the dry season (December to February) and the rainy season that runs from May to October due to the African monsoon (USAID, 2013). According to USAID (2013), Liberia's coastal location allows the southwesterly flow of the monsoon to prevail most of the year, maintaining a thin layer of moist marine air near the surface. The moisture-laden West African Monsoon winds from the southwest strike the Liberian coast head on, increasing coastal rainfall despite the gradually increasing elevation inland. The average annual rainfall in the coastal belt is more than 4000 mm with individual months receiving more than 1000 mm of rainfall (McSweeney et al. 2008).

Where the monsoon winds meet high coastal promontories (e.g., Cape Mount, Monrovia), the annual rainfall is much higher than average for the coastal region. In the interior, precipitation is less abundant and it drops below 2,000 mm per year (EPA, 2013).

Temperature in Liberia is determined by its tropical location, where the sun is almost overhead all year (Gatter, 1997). Generally, the country experiences high temperatures all the time that show little variation. The temperature over the whole country ranges from 27-32° C during the day and from 21-24° C at night (MPEA, 1983). Average annual temperatures along the coast range from 24-30° C (MPEA, 1983). The temperature rises slightly in the dry season and decreases in July and August. Towards the interior of the country the average maximum rises and the average minimum decreases.

Temperatures in Liberia are strongly influenced by season; the dry season and the rainy season (USAID, 2013). For the period of 1970-1999, temperatures typically ranged from 24 to 25° C during the wet season and 24 to 27° C during the dry season (McSweeney et al. 2008). These temperature ranges are consistent with those reported by Coolidge (1930) of 24 to 26° C during the wet and 24 to 29° C during the dry season. It is difficult to determine whether there is a long-term trend in rainfall due to the high variability exhibited in the rainfall record. McSweeney et al. (2008) note that the observational record is punctuated with particularly wet (1960s and late 1970s) and dry (early 1970s and 1980s) periods.

This variability is also noted today as 2005-2006 were noted as dry years while 2007-2009 were wet. However, USAID (2013) notes that temperature trends are difficult to discern from the observational record. From 1960 to 2006, mean annual temperature increased by 0.8° C (McSweeney et al. 2008). However, extending the time period back before 1930 (using data from Coolidge, 1930) reveals a slightly negative trend to date.

<u>Expected Future Climate:</u>

The analysis of USAID (2013) climate change assessment different scenarios predicts an increase in temperature conditions across Liberia. According to the Environmental Protection Agency (EPA, 2013), the projected climate of Liberia from 2010 – 2050 is based on an ensemble of Regional Climate Models (RCMs). Mean air temperature is unanimously projected to increase by 0.4°C to 1.3°C by 2050 in the models. In the 2020s the average increase for temperature is estimated at 0.6°C. It appears that temperature will increase by 1.3°C by the middle of the 21st century (EPA, 2013).

Other projections according to EPA (2013) reveal that Liberia's future climate for 2050 and 2080 will be marked by a warmer climate in most parts of the country with some areas drier than current. It is projected that most parts of the country will experience an increase in temperature at 1° to 2° during the hottest month (February) compared to current temperature. Using historical data from the World Meteorological Organization station of neighboring countries, the statistical downscaling scenario reveals that temperature change will be less than 2°C throughout the country but nighttime temperatures will increase by more than 2°C in the interior of the country (EPA, 2013). A comparison of current average maximum temperature with 2050 projections in February, which is the hottest month, reveals an increase in temperature for most part of the country at 1° to 2°, with the highest temperature of 36°C in the interior. Similar comparison for average low temperature reveals a 2°C increase in nighttime temperature along the coast in the west and the northeastern border area (EPA, 2013).

The average increase for rainfall in 2020s is estimated at 3% (EPA, 2013). Comparing the current to 2050 spatial pattern of average annual precipitation, other projection also shows that there will be a slight increase in total rainfall towards the inland in the future, with the greatest average annual precipitation (5,000 mm) projected along the western coast in 2050 (EPA, 2013). It is also projected that there will be an increase in rainfall along the coast during the wet season while the inland regions will see normal to slightly reduced rainfall. Due to the projected increase in temperature in the ocean by 2050, the northern parts of Liberia will experience drier conditions, while rainfall along the southern coast will increase in May (USAID, 2013). These projections show a spatial variability in precipitation with a warmer Atlantic Ocean and reduced inland temperature that result to less rainfall in the interior.

Climate change Impacts on Vulnerable Coastal Areas:

Various global climate models project a sea-level rise in Liberia of 0.13 to 0.56 m by the 2090s relative to the sea level from 1980-1999 (McSweeney et al. 2010). Liberia has a low infrastructure capacity for basic social services, making the country highly vulnerable to climate change. DAI (2008) reported current beach erosion rates are as high as 3 m/yr with ongoing structural damage and loss. According to USAID (2013), the underlying rates of erosion are likely primarily related to natural conditions (e.g., geology, longshore currents, wave action). In 2005, it was projected that a rise in sea level by 1 m, would cause a loss of about 95 km^2 of the estimated 580 km long coastline (due to inundation); and 50% of the area inundated (48km^2) will be areas with settlement such as parts of the capital city of Monrovia, River Cess, Buchanan, and Robert Sport, which are less than 1 m above mean sea level (Wiles, 2005). This was projected to result in a loss in infrastructure and land of around $250 million apart from the social and psychological stress to the population, with women and children being particularly vulnerable (Tumbey, 2015).

<u>Climate Change Impacts on Forestry:</u>

In Liberia, the natural forests cover about 4.3 million hectares or 45 percent of the land area, and the artificial forests cover about 11,000 hectares. The forest areas have continued to decline mainly due to unattainable agriculture and inappropriate commercial logging. According to EPA (2016), additional pressure is being created by climate change (unreliability of rainfall, over-flooding of settlement and farmlands and disparity in weather pattern) resulting in the need for massive clearing of forest for agricultural production and settlement. A changing climate influences the structure and function of forest ecosystems and plays an essential role in forest health. In fact, increased temperature as a result of climate change has started to expand the ranges and to enhance the survival rates of forest pests such as the case of the armyworm caterpillars' outbreak which occurred in rural Liberia in 2009.

1.4.2 Process and results of sector selection

As Liberia participates in the TNA process for its first time, the national TNA coordinator and stakeholders (Annex II) followed the TNA guideline/ recommendations using multi-stakeholders to select sectors of high priority in regards to both mitigation and adaptation measures to climate change impacts. Headed by the EPA, the process commenced with the approval of the National TNA coordinator and a committee. From October 23rd to 26th of 2018, the team then conducted a mapping of stakeholders that was followed by a national stakeholder's validation at the TNA inception workshop in Monrovia that was attended by a team of TNA's international partners from UNEP - DTU Partnership (UDP) and the Energy Research Centre (ERC).

The sector prioritization process considered presentations of climate change impacts, risks and vulnerabilities to the society, the overall objectives of the TNA project and the importance of stakeholders involvement. The inception workshop provided information and clear understanding to stakeholders. The knowledge acquired was used by the stakeholders to make informed decisions in regards to sector identification and selection, and as well as the prioritization of technology options for adaption and mitigation of the TNA process in Liberia. The following criteria were established and used for sector selection and technology’s prioritazation.

- Current mitigation and adaptation needs;
- National priority based on policy and development plans;
- Sectors to be prioritized should have some ongoing activities that the TNA project will compliment;
- Sectors for adaptation should be those that are most vulnerable to the impacts of climate change.

In accordance with the established criteria, two sectors were selected for adaptation:

1. Agriculture;
2. Coastal Zone.

Liberia’s climate change and vulnerability assessments considered three major sectors to be vulnerable to climate change. These sectors were pointed out and prioritized in the country’s NAPA. They are agriculture, hydro-meteorological and coastal zone. The coastal zone and agriculture sectors are prioritized for climate change adaptation considering the following criteria but not limited to:

- Vulnerability to climate change;
- Adaptive capacity;
- National priority based on policy and development plans;
- Socio-economic importance;
- Technological feasibility;
- Potential impact on large segments of the population.

Chapter 2: Institutional arrangement for the TNA and the stakeholder involvement

In order to successfully carry-out the TNA process in Liberia for the first time; the country's most important national institutions involved in environmental or climate change policy making that are considered vital to the TNA process were solicited, namely the Environmental Protection Agency (EPA) and the Ministry of Mines and Energy (MME). Environmental Protection Agency (EPA): The EPA is the lead on the TNA process. The EPA is the regulatory authority of the government of Liberia for the management of the environment, and mandated to coordinate, monitor, supervise, and consult with the relevant stakeholders on all activities in the protection of the environment and sustainable use of natural resources; promote environmental awareness and implement the national environmental policy and the environmental protection and management law; and oversee the implementation of international environment related conventions.
Ministry of Mines and Energy (MME): The MME is the government institution that is responsible to administer all activities related to mineral, water and energy resource exploration, coordination and development in the Republic of Liberia. In particular to the TNA process, the MME has an established unit called the "Integrated Coastal Zone Management Unite" (ICZMU) responsible for both adaptation and mitigation options relating to coastal risks and vulnerabilities. Therefore, the MME gives support to the EPA with respect to the coastal zone.

As it relates to the TNA project, the environmental protection agency (EPA) of Liberia, which is the regulatory authority for the management of the nation's environment is the lead and host for the TNA in Liberia. The EPA is assigned with the overall responsibility for the implementation of TNA activities. It is with said responsibility to coordinate, monitor and supervise the TNA project that the EPA did consult with the relevant government ministries, agencies, stakeholders, non-governmental organizations (NGOs), private sectors, and community representatives for the selection of the sectors to be covered by the first phase of the TNA project in the country.

This process successfully resulted to the selection or prioritisation of the nation's three (3) key sectors currently covered by the TNA process in Liberia; (Mitigation: Energy) and (Adaptation: Agriculture and Coastal zone).

To achieve the objective of the TNA process, each of the above relevant institutions works in partnership with the EPA in providing support to each sector which falls under its supervision to facilitate the process.

2.1. National TNA team

- National Steering Committee
- TNA National Coordinator (Mr. Christopher B. Kabah);
- National Consultants of the identified sectors (Coastal Zone, Agriculture & Energy);
- Technical working group of each identified sector.

A National TNA team was set-up by the Environmental Protection Agency of Liberia which is the national leading institution for the TNA process in overseeing the implementation of the project. Nationally, the TNA project is hosted within the department of climate change at the EPA; and the national steering committee supervises, coordinates and facilitates the progress of the project's activities through the national TNA's team. The committee consists of high level officials from key Government institutions and sectors; namely:

1. *" President of the Republic of Liberia – Ex-official*
2. *Energy, Environment and Climate Change Advisor to the President of Liberia*
3. *Heads of Standing Committees on Environment and Natural Resources of the Senate and the House of Representatives*
4. *Minister of Planning and Economic Affairs (MoPEA)*
5. *Minister of Lands, Mines and Energy (MoLME)*
6. *Minister of Agriculture (MoA)*
7. *Minister of Finance (MoF)*
8. *Minister of Gender and Development*
9. *Minister of Transport*
10. *Minister of Finance & Development Planning*
11. *Managing Director of the Forestry Development Authority*
12. *Executive Director of the Environmental Protection Agency*
13. *Chairman, National Investment Commission*
14. *Commissioner of Liberia Maritime Authority*
15. *World Bank*
16. *University of Liberia*
17. *Civil Society*
18. *Fauna & Flora International*
19. *NCCS Coordinator"*

This committee was established in 2010 as the policy coordination body for the overall climate change activities in Liberia (Republic of Liberia, 2018).
The National TNA Team works in consultation with the national steering committee that is the main decision making body for the project, as the TNA Coordinator is the focal-person responsible for overall overseeing of the process and the national focal point.

The national adaptation and mitigation consultants and technical working groups assist in the formation of networks, and compilation of information, coordination and communicating all project products. The stakeholders provided inputs to the TNA through a selection of sectors and technologies, as well as deciding on which technologies are most suited to the country situation. Technical assistance was provided by UNEP DTU Partnership for the commencement of the TNA process in Liberia. The consultants (who worked closely with the TNA Coordinator) analysed country specific information, as well as information provided by UNEP DTU, to come up with country specific analysis. The information was hereafter analysed and synthesised in accordance with TNA guidebooks provided by UNEP DTU.

The stakeholders' technical working group on coastal zone was central to the TNA process as they participated in discussions leading to the identification of sectors, and prioritisation of technologies using the TNA's MCA methodology. The working group was also involved and participated in additional working sessions during the compilation of this report, after the technology prioritization process on April 1st 2019.

Table 2: below, is the list of institutions and organizations represented on the coastal zone stakeholders' technical working group for adaptation. A detailed list of Stakeholders' names and information on the coastal zone technical working group of technology prioritization is presented in annex-II.

Table 2: Institutions and organizations represented on the Coastal Zone adaptation working group:

Coastal Zone Technical Working Group
1. Ministry of mines & Energy (MME) 2. Environmental Protection Agency (EPA) 3. Community Youth Empowerment (CYE) 4. Ministry of Gender, Children and Social Protection (MoGCSP) 5. Ministry of Internal Affairs (MIA) Alliance Consulting Engineers (ACE) 6. University of Liberia (UL) 7. Ministry of Commerce and Industry (MoCI) 8. National Fishery Authority (NaFAA) 9. Initiative for Youth and Children Advancement (I-IYOCA)

The organisational structure of the TNA project in Liberia is shown in Figure 1. It is adopted from the UNEP DTU Partnership TNA guidebook *(TNA Step by Step – A guidebook for countries conducting a Technology Needs Assessment and Action Plan)* for better coordination (Haselip *et al*., 2019).

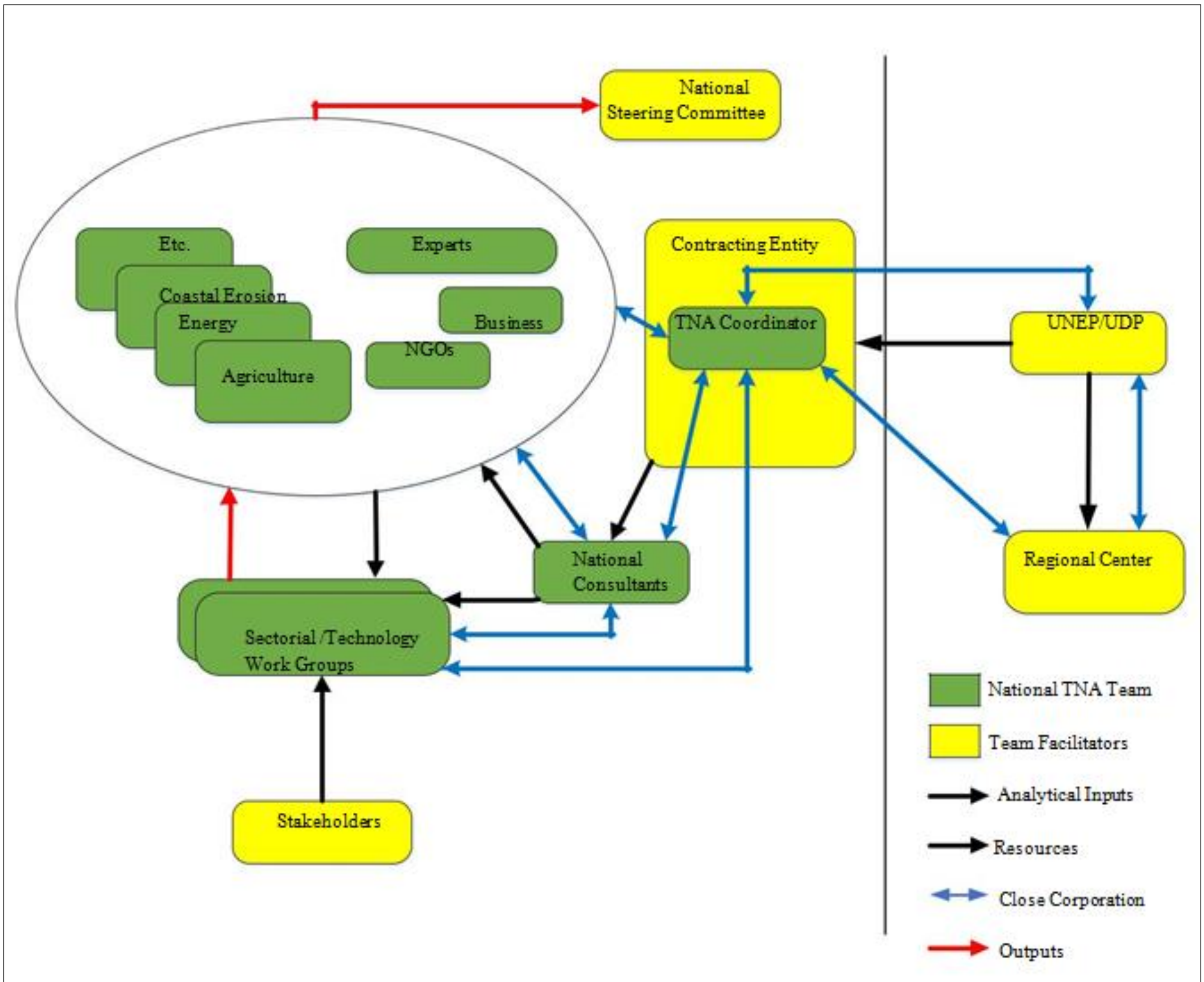

Figure 1: Organizational structure of the TNA process in Liberia.
Source: Adopted from the UNEP DTU Partnership TNA guidebook *(TNA Step by Step – A guidebook for countries conducting a Technology Needs Assessment and Action Plan)*; (Haselip *et al*., 2019).

2.2. Stakeholder Engagement Process followed in the TNA – Overall assessment

With the help, and in accordance with a guidebook provided by UNEP/DTU (Pía, 2015); Stakeholders were engaged, and got involved in the TNA process from the beginning of the inception mission in October of 2018 which included the participation and visit of UNEP, DTU and the Energy Research Centre representatives to Liberia.

After the inception mission workshop was conducted, the national TNA team was formed and started to move forward with the TNA process in Liberia. In order to identify the key climate change affected sectors and technologies prioritisation, key stakeholders, government ministries, agencies, Non-governmental organizations (NGOs), Private institutions, Research institutions/ organizations (Universities) were identified.

These institutions covered a range of sectors of interest to the TNA process such as water, biodiversity, agriculture, energy, health, industry, academia and civil society. In so doing, invitations were then sent to the identified institutions about the TNA process to be carried out in the country.

Having successfully identified the three sectors, factsheets were then developed by the national consultants of each sector and sent to the stakeholders' technical working group of their sector to have them prepared for the inception workshop of technology prioritization (*Figure: 2*). The coastal zone technical working group consisted of eleven members including the coastal zone national consultant (Annex II). In particular, ten technology factsheets were developed for the coastal zone sector. On the 1st of April 2019, a technology prioritization workshop for TNA was held in Monrovia, where stakeholders prioritised some technologies for each sector using the Multi criteria analysis (MCA) of the TNA process. During this workshop, the coastal zone sector prioritised three technologies of the ten identified technologies, and these are detailed in chapter: 3.

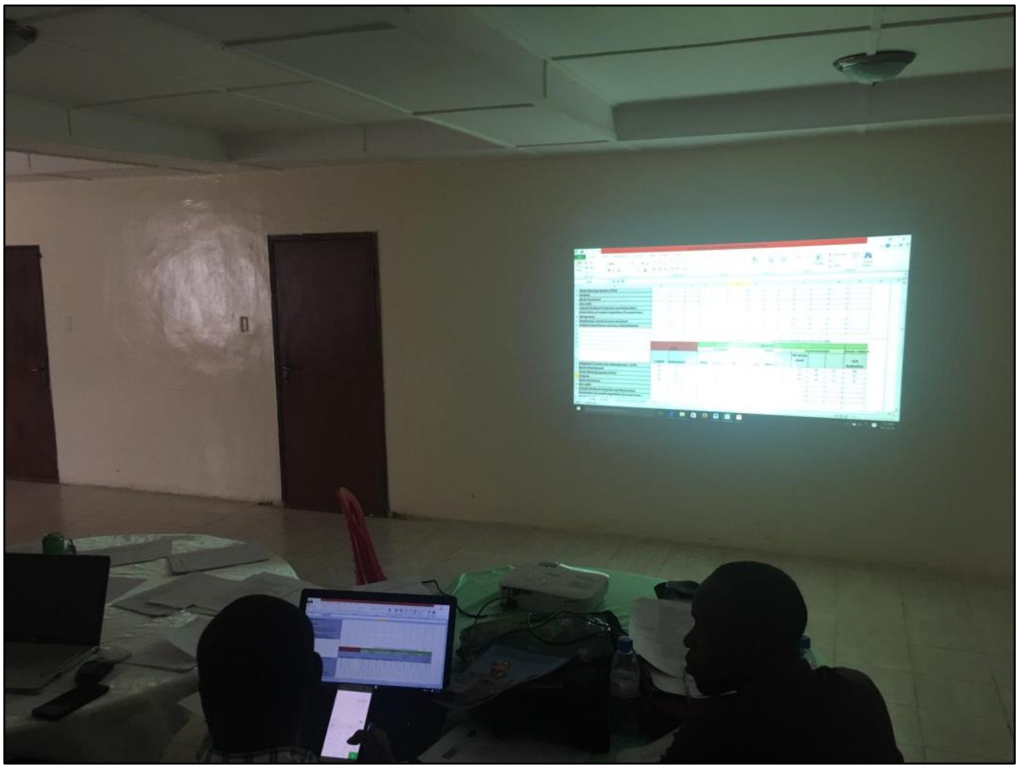

Figure 2: Coastal zone technology prioritization process; April 1, 2019.
Source: Personal; taken on April 1st 2019.

2.3. Consideration of Gender Aspects in the TNA process

In order to have a gender balance or representation considered in the TNA process, the coastal zone sector included both male and female representation in its technical working group following the guidelines provided by UDP in *'Guidance for a gender-responsive Technology Needs Assessment'* available at www.tech-action.org. The gender aspect was also considered during the development of the coastal zone technologies' factsheets; and as the consultant, local coastal communities that are highly affected by the impacts of coastal erosion and flood were visited to solicit the views of women, youth and community leaders as to what adaptation measures could be considered that wouldn't interrupt their socio-economic activities, livelihoods and environment. Their recommendations inserted below were noted and carefully considered during the coastal zone technology prioritization process.

The technical working group on the coastal zone consisted of eleven (11) members including the coastal zone national consultant, who is the head of the group. Four (4) of the eleven (11) members technical working group are females. This constitutes 36.4% of female representation for the TNA coastal zone technology prioritization process. Below are some of the views and recommendations from affected vulnerable coastal communities visited.

<u>Example of some recommendations from coastal residents:</u>

- ***Relocation Option:*** It was noted that majority of the residents in the West-point township and the New Kru-town community areas do not recommend and support relocation elsewhere inland as an option despite of the ongoing destruction of properties by coastal erosion and flooding there. Most of the residents pointed-out that their livelihoods strongly depend on fishing and other coastal related activities; as such, leaving the coastline shall make life difficult because fishing is what majority of them do for living. This reveals why a government project /decision to relocate the residents of the West-point Township was not successful despite housing facilities were provided during the leadership of President, Ellen Johnson Sirleaf.
- ***Coastal Defence Option:*** It was observed and noted that residents of climate change vulnerable coastal communities in Liberia prefer hard engineering coastal defence systems such as a *revetment* as an option to adapt to coastal erosion and storm surge related threats. *Fishermen and Youth* in these communities recommended that a coastal defence system such as a sea-wall or revetment should be designed in a way that their fishing and social activities should be considered. Example, (discontinued revetment): they recommended that the revetment rocks should not cover the entire coastline of the community; space or spaces should be left in the design. For the Fishermen: *"the spaces will be used for our canoes and boats to get on the beach".* For the Youth: *"the same spaces will be used for our social and recreational activities such as swimming".*
- ***Policy and Governance Option:*** The Women who are the main actors in the fishing activities (processing and selling of fish) on the beaches in coastal communities of Liberia recommended the following, amongst others:
    - *Mitigating beach degradation by human activities: Specific locations should be allocated along the beaches for processing and selling of fish and parking of fishermen canoes and boats to limit beach degradation through human activities;*
    - *Stop beach sand mining in residential coastal areas;*
    - *Form and support a "Community Female Coastal Action Group" in each climate change affected and vulnerable coastal community to uphold adaptation rules and regulations.*

- *Involvement of vulnerable coastal communities' participation at government / stakeholder level in decision making or policy formulation that shall be applied to affected and vulnerable coastal communities of climate change impacts.*

Chapter 3: Technology prioritisation for the Coastal Zone Sector

The coastal zone is one of the nation's greatest environmental and economic assets. However, the evolution of coastline variations is considered as one of the most dynamic processes affecting this area. Therefore, understanding the dynamics and the mechanisms that control this zone is essentially important for its management and planning. Coastal erosion and flood impacts have become a national concern as many coastal communities along the about 580 km long Liberian coastline, from Cape Mount (NW) to Maryland (SE) have become vulnerable to climate change related impacts.

To therefore adapt to these issues, many vulnerable coastal communities were visited to analyze the situation. Some of the vulnerable coastal communities visited include, amongst others: West-point township *(Figures: 4a & 4b)* and the New Kru-town community near Monrovia *(Figure: 5);* the Fanti-town community and the Atlantic Street in Buchanan Grand Bassa county; the Mississippi street in Greenville, Sinoe County *(Figure: 3);* Harper city and Fish-town *(Figure: 6)* in Maryland county.

During these visits/ assessments, discussions were held with residents to solicit their views about the impacts of the flood and erosion situation affecting their communities. In accordance with the technical analyses of the erosion and flood impacts on social, economic and environmental issues, as well as the residents' concerns and recommendations, the TNA national consultant for the coastal zone developed factsheets of ten (10) adaptation technologies to be used for the TNA technology prioritization process.

The factsheets were sent to stakeholders and members of the technical working group before the prioritization process. The coastal zone technology prioritization for adaptation was conducted using the TNA Multi Criteria Analysis (MCA) model, for which the three highest ranked of the ten adaptation options were retained.

3.1. Key Climate Change Vulnerabilities in the Coastal Zone Sector

Currently in Liberia, the coastal zone is faced with the following climate change impacts that have become a national concern for which; if immediate and sustainable actions are not taken to mitigate or adapt, the situation shall worsen. Coastal erosion *(Figures: 3 & 4a)*, Coastal flooding and Marine/ Saline intrusion into fresh drinking waters *(Figure: 4b)* are currently the most common climate change impacts that are destroying lives, property, coastal ecosystems, socio-economic activities and etc. in majority of Liberia's coastal areas. These climate change impacts in coastal cities along Liberia's coastline were observed / identified during a National Coastal Vulnerability Assessment conducted in March and June of 2019 in which I participated representing the TNA EPA project. As thousands of the coastal residents become homeless from the impacts of coastal flood and erosion along the Liberian coastline: West-point, New Kru-town, Greater Monrovia and others of Montserrado county, Atlantic street, Fanti-town of Grand Bassa county, Robert's Sport of Cape mount county, Greenville of Sinoe county, Harper of Maryland county are the most vulnerable; as many more become and remain vulnerable (*Figures: 3 & 4*).

According to Liberia's "*National Policy and Response Strategy on Climate Change 2018"* (NPRSCC, 2018), Settlements in coastal lowlands of Liberia are especially vulnerable to risks resulting from climate change; yet these lowlands are densely settled and growing rapidly (McGranahan et al., 2007). For example, it is projected that about 95 km^2 of land in the coastal zone of Liberia will be inundated as a result of one-metre sea level rise, with about 50% (48 km^2) of the total land loss due to inundation being the sheltered coast (Wiles, 2005). The Inundation will be followed by shoreline retreat (Wiles, 2005); yet the population of Monrovia continues to grow. The potential rise in sea levels could add to existing trends of coastal erosion in areas like Buchanan, Monrovia and Greenville with a loss in infrastructure and land of around $250 million apart from the social and psychological stress on the population (Tumbey, 2015; Wiles, 2005).

It is in connection with the above, that the coastal zone technical team and some stakeholders have identified and prioritized technologies of adaptation and mitigation that will enable the country to achieve social equity and environmental sustainability that will follow a low vulnerability development path.

Figure 3: Destruction of Mississippi Street by coastal erosion, Greenville – Sinoe County, Liberia. ***Source:*** Personal; taken on June 20, 2019.

A **B**

Figure 4: (**A**), Destruction of properties and (**B**) **-** Intrusion of sea/ salt-water into wells; West-point Township; Monrovia – Liberia. ***Source:*** Personal; taken June 16, 2019

3.2. Decision context

There are many efforts and initiatives that have been taken to address the alarming impacts of coastal erosion, coastal flooding and marine or saline intrusion into fresh drinking water that are disrupting livelihoods, destabilizing socio-economic activities and accelerating environmental degradation. To mitigate or adapt to some of the impacts, climate change projects/ programs were and are still being facilitated and implemented in Liberia; among which some major adaptation projects in climate change vulnerable communities are as follow: .

The Coastal Add-On project (CAP): funded by the Global Environmental Facility (GEF) through the United Nations Development Programme (UNDP) seeks to Enhance Resilience of Liberia's Montserrado County Vulnerable Coastal Areas to Climate Change Risks. The CAP constructed from June 2018 to June 2019, some 900 (Nine Hundred) linear meters coastal defense "Revetment" in the D-Twe Kru-town area. The project seeks to reduce the vulnerability of the community's population and natural coastal environment to climate change risks and enhance the capacity of the community to recover from coastal erosion impacts (*Figure: 5*).

Buchanan Coastal Defence Project: also a CAP, supported by the UNDP and implemented by the Ministry of Mines and Energy during 2016 to 2017. This project constructed about 250 linear meters of coastal defense (revetment) in Buchanan city, Grand Bassa County, along the Fanti-town and Atlantic street area to mitigate the alarming rate of coastal erosion that was of national concern.

Liberia Climate Change Assessment (2013) was a project implemented by the United States Agency for International Development *USAID-Liberia Mission* to assist the Government of Liberia to develop climate data. In an effort, this project assessed and developed a climate data and future climate projections for the country. The project presented the level of coastal vulnerability identified in the coastal zone of Liberia from climate change impacts and recommended sustainable intervention. The result of this assessment for the coastal zone is an asset to be used by stakeholders to solicit funding from climate change donors in order to implement coastal mitigation and or adaptation measures projects.

Some additional policy documents, programs and projects developed to sustainably minimize the level of vulnerability to climate change and linked to existing development efforts include:

- *"Liberia's National Adaptation Plan Process (NAP)"*
- *"National Disaster Management Policy of 2012",*
- *"Liberia National Adaptation Programme of Action (NAPA, 2008*)"
- *"Liberia forest sector project (2016), Report No: PAD1492"*
- *"The Land-use & Zoning code of Liberia",*
- *"Liberia's Intended Nationally Determined Contributions (INDC, 2012)"*
- *"NDMA Nation hazard contingency plan"* and etc.

Figure 5*:* CAP Coastal defence project (Revetment), D-Twe, Kru-Town: Monrovia – Liberia
***Source**:* Personal; taken in March of 2019.

3.3. Overview of Existing Technologies in the Coastal Zone Sector

Hard engineering measures and technologies to mitigate and adapt to climate change hazards that are occurring in the coastal zone of Liberia are not yet widely spread. However, there are few recent and major projects of hard engineering coastal defence (revetment) located in Monrovia (Figure: 5) and Buchanan to mitigate the high rate of coastal erosion and that of the ocean wave's energy related to climate change sea level rise that have resulted to the loss of properties and disruption of some natural ecosystems in the coastal areas. Break-water defence systems are constructed along the four major seaports of the Liberian coast (Monrovia, Buchanan, Greenville and Harper).

Hard engineering coastal defence measures are commonly used in and around Monrovia. Interestingly, during the National Coastal Vulnerability Assessment of 2019, we observed that the soft or green measures of coastal defence systems have been practiced in Maryland and Grand-Kru Counties for many years. These green measures consist of planting of coconut and almond trees along the beaches (Figure: 6). According to residents of the two counties, the planting of the trees started during the 1950s in the Maryland areas and the 1980s in the Grand Kru areas. We have come to understand after interviews with some of the residents in those counties; that coconut trees or plantations along the beaches were primarily planted to be used as food or for agriculture purposes; such as a means to generate income. The trees also reduce the velocity of the ocean's wind that most often destroys the roofs of their homes.

Figure 6*:* Green adaptation measure (Coconut trees) to coastal erosion impacts: Fish-town, Harper Maryland County- Liberia. ***Source:*** Personal; taken on July 2nd, 2019

However, those coastal communities have realized that the trees are also serving as a preventive measure against coastal erosion (figure: 6). Beaches with almond or coconut trees plantation are much more stable when compared to those without the coconut trees. Residents are highly encouraged to plant more trees as they appeal for external assistance. Nevertheless, the coastal technical working group recommends and encourages the wide spread of such green measure / technology to be applied across Liberia as it is environmentally sustainable.

3.4. Adaptation Technology Options for Coastal Zone Sector and Their Main Adaptation benefits

The table below shows a list of coastal zone technology options and their adaptation benefits; some technologies are cross-cutting (adaptation & mitigation). The technologies listed here within, were each developed a factsheet (TFS) with detailed description that were used to facilitate the stakeholder consultation during the TNA coastal zone technology prioritization process for Liberia on April 1st 2019.

Table 3*:* A list of ten coastal zone adaptation technology options, this list was used for the technology prioritization process.

No.	Technology Option	Main Benefits
1	Artificial Sand Dunes and Dune Rehabilitation	▪ The purpose of this technology is to prevent further coastal erosion and flooding as well as helping to dissipate incoming wave energy ▪ Promotes safe interface between the sea and land, limits

		negative effects on landscape and restores a degree of natural character to places that had naturally occurring dunes complexes before development. ▪ Conservation of diverse, unique biodiversity and landscapes, and provides valuable coastal habitats for many highly specialized plants and animals. ▪ Attracts recreational activities that could promote coastal eco-tourism. ▪ Shall provide employment opportunities for women, students and small/medium machinery establishment. ▪ Creates a path-way to multiples management objectives, such as habitat protection, public access to environmental and recreational resources and hazard mitigation; & etc.
2	Beach Nourishment	▪ The logic behind beach nourishment is to turn an eroding, reflective beach into a wider, dissipative beach. ▪ Addresses sediment deficit: the underlying cause of erosion. ▪ Beach nourishment is a soft coastal management measure that doesn't disturb coastal natural processes or have adverse impacts on neighbouring areas in contrast to most hard coastal engineering approaches. ▪ Shall provide job/employment opportunities; ▪ Attracts tourists, and promotes coastal tourism and recreational activities.
3	Flood Warning System (FWS)	▪ In general, it aims to reduce the degree of casualty that could be caused by coastal flooding through alerting the public in advance to take appropriate actions (Response); ▪ Detects threatening events in advance to help protect lives and properties. ▪ The data collected (Tidal, Meteorological, wave, river, wind and etc.) for the said service could also be used for mitigation and sustainable environmental planning. ▪ Promotes human capacity building as a FWS requires technical training of monitoring and forecasting ▪ Creation of job opportunities.
4	Groynes	▪ Minimizes long shore drift and trap sediment. By doing so, they help to build and stabilize the beach environment; ▪ Reduces coastal erosion hazard and promotes coastal tourism; ▪ Promotes the formation of coral reef, and attracts many coastal species; ▪ Reduces coastal vulnerability to climate change impacts; ▪ Nationally promote rocks quarry industry/ business and creates job opportunity; ▪ Helps in stabilizing the beach environment and reduces coastal erosion on beach significantly;

		▪ Low maintenance costs
5	Integrated Coastal Zone Management (ICZM)	▪ Dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones; ▪ ICZM seeks over the long-term, to balance environment, socio-economic, cultural and recreational objectives; ▪ ICZM Reduces ecosystem degradation; and also conserves and maintains existing ecosystems from potential climate change impacts; ▪ Manages / protects coastal resources in a sustainable way; ▪ Involvement of local communities or stakeholders participation in decision of sustainable environmental management. ▪ Multi tasks and conflicts solving in using sustainable and efficient coastal management; ▪ Provides appropriate measure to address short and most importantly long-term challenges in coastal zones; ▪ Protects lives and properties by reducing coastal vulnerabilities and risks; ▪ Establishment of communication and coordination strategies; involvement and participation of relevant authorities and etc.
6	Monitoring of Coastal Erosion and Flooding	▪ Helps to save lives and as well, informs vulnerable coastal communities to take appropriate actions that will reduce the impacts on homes, businesses, infrastructure, ecosystem, and etc. from coastal erosion and related flooding hazards. ▪ Shall provide job opportunities to coastal communities, coastal engineers, GIS specialists, Environmentalists and etc. ▪ Promotes scientific research, coastal data collection and contributes to human capacity building; ▪ Encourages and protects investment and development of the coastal zone;
7	Restoration /Planting of coastal vegetation or trees (Coconut trees , Mangroves)	▪ Prevents coastal erosion and inundation and promotes ecosystem restoration; ▪ Enhances the restoration of biodiversity through the promotion of habitat, specific targeted species; ▪ Minimizes risk of coastal inundation and erosion of coastal environments and reduces risk of properties to be damaged by coastal hazards (coastal erosion, coastal landslide, inundation, etc.). ▪ The selected Coastal vegetation with dense root system is very effective at holding onto the sand and reduces the rate of dune erosion or degradation caused by waves or winds actions; ▪ It provides protection against coastal erosion, inundation and

		will minimize the negative impacts on beaches from natural phenomena. ▪ Improves stability of dunes and ecosystem, biodiversity and also provide food and shelter for coastal wildlife. ▪ Improvement of scientific knowledge on the sensitivity and ecological importance of coastal vegetation. ▪ Shall provide employment opportunities to persons involved in coastal zone management sector, nurseries management, and ecotourism centers and most importantly, it is feasible by women; therefore, promote gender balance empowerment.
8	Armour or Rocks Revetment	▪ Protects against erosion caused by wave action, storm surge and tidal effects; ▪ Shall easily be widely adapted nationally due to the availability of ideal rocks quarries; ▪ Protects and fixe the boundary between the sea and land; these actions protect and assist in maintaining the landward environment; ▪ Rocks revetments also minimize the destructive and hazardous risks to coastal ecosystem, vegetation, sand dunes and important infrastructures. They also prevent coastlines which are subjected to erosion, high wave impact and coastal flooding from related degradation; ▪ Provides high level of security which can favour the development of coastal communities; ▪ Not very expensive and has low maintenance cost as compare to other hard defence systems.
9	Seawall (SW)	▪ Resists the full force of incoming waves; ▪ Prevent coastlines which are subjected to erosion, high wave impact and coastal flooding from degradation; ▪ Aims to protect upland infrastructure from flooding, wave impacts, and over topping; it also helps to hold land fill (bluff, shoreline) in place; ▪ Minimize the destructive and hazardous risks to coastal ecosystem, vegetation & sand dunes, important infrastructure or buildings and businesses located along the shoreline; ▪ Encourages educational and scientific development; ▪ Its implementation shall provide employment to professional individuals (coastal, marine, geotechnical engineers, equipment renters and etc.) involved in coastal sector.
10	Coastal Wetland Protection and Restoration	▪ Reduces the incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone; ▪ This reduces the erosive power of waves and helps to reduce coastal flood risk by diminishing the height of storm surges; ▪ Provides a number of important ecosystem services including water quality and climate regulation;

		▪ This option reduces wetlands losses as a result of climate change; ▪ Shall create jobs for local coastal communities, and contribute toward local sustainable development. This can also create opportunities for eco-tourism and increase recreational opportunities.

3.5. Criteria and process of technology prioritisation

The selection of the three retained technology options of Liberia's coastal zone sector by the technical working group was based on the technology's potential to reduce vulnerability to climate change, and social, economic, and environmental benefits using the TNA "*Multi Criteria Analysis (MCA)"*. The MCA provides a structured framework for comparing a number of technologies against multiple criteria *(Section: 3.6; Figures: 7- 9).*

In order to initiate the MCA process, technology factsheets (TFS) were developed with detailed information regarding cost and benefits for each of the options by the coastal zone consultant for the ten (10) technology options listed in chapter 3.4, that were identified along with the stakeholders. Soft copies of the detailed factsheets in "*Annex-1"* were initially sent to stakeholders and members of the technical working group via email for familiarisation with the technology options. During the technical working session, hard copies of the same TFS were distributed to them for the technology prioritization process. However, out of the ten technology options that were identified, just eight (8) of them were considered to be used for the technology prioritization process because the technical working group suggested that some of the technologies were similar and could serve the same purpose. Therefore, two of the technology options were eliminated after a technical review (*Monitoring of coastal Erosion and Flooding* and *Artificial sand dunes and dune rehabilitation*). Nevertheless, the ten TFS are inserted here within this report *(Annex: I).*

Understanding and Identifying Criteria and Indicators**:** as the TNA "*Multi Criteria Analysis (MCA)"* methodology was adopted for the coastal zone sector, the coastal consultant had the task to ensure the coastal technical working group understood the meaning and importance of the different criteria and indicators in accordance with the TNA's MCA broadly two sets of criteria's categories (Cost & Benefits) to evaluate.

With every member of the technical working group having an understanding of Criteria being the measures of performance by which the options will be judged, the working group along with the coastal consultant identified the criteria and indicators that were used to carry out the prioritization of coastal technologies. The process considered the national developmental goals to improve resilience to climate change impacts, socio-economic and environmental sustainability in the coastal zone sector with respect to their cost and benefits.

Scoring matrix: The scoring normalization scale for each criterion was from zero (0) to hundred (100), using zero as the least score and hundred as the highest. To reach a score for each technology against the criteria, the coastal zone technical working group agreed that an individual expert scoring should be publicly announced in the working session and then be written or submitted on a scoring sheet to the MCA facilitator (coastal consultant) who then publicly calculated the average score.

Weighting: After the technology options have been scored against all the criteria, each criterion was then given a weight to reflect the weight of importance that stakeholders assigned to each of the specific criteria (Cost = 20% and Benefits = 80%). Weight values of the "criterion weight" of zero (0.0) to one (1) was adopted; the "1" was considered as hundred (100) to reflect the actual zero (0) to hundred percent (100%) scoring range within the decision matrix of weighted scores for each technology options in accordance with the different indicators.

The cumulative sum of weights across all indicators was equal to one (1) which also meant hundred (100) as stated above. When the criteria have been weighted, the weighted scores against all criteria for each of the technology options were then added to derive at an overall value score. The total weighted score results for each technology was then compared and ranked to select the three highest values.

3.6. Results of technology prioritisation

The result of the MCA for technology prioritization of the Coastal Zone Sector of Liberia is summarized in *Table: 4* below. The technologies are arranged in accordance with their ranking. *Table 5* consists of a brief description of the first three highest ranked or selected technologies. *Figures 7 to 9* present the results of the MCA Excel calculator for the overall score of each technology. The detailed factsheets for each of the selected technologies are available in Annex 1.

Table 4*:* Ranking of the technology prioritization results for the coastal zone.

Rank	Technology	Weighted score
1	Integrated Coastal Zone Management (ICZM)	80.99%
2	Flood early Warning System (FWS)	69.47%
3	Rock/ Armour Revetment	61.31%
4	Groynes	48.11%
5	Sea-walls	44.12%
6	Beach Nourishment	44.07%
7	Coastal Wetland Protection & Restoration	40.79%
8	Restoration of coastal vegetation (Coconut trees, Almond trees, Mangroves & etc.)	40.43%

Table 5*:* A brief description and benefits of the first highest three ranked technologies.

Rank	Technology	Brief Description	Benefit
1	Integrated Coastal Zone Management (ICZM)	ICZM is a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. The ICZM seeks over the long-term, to balance environment, socio-economic, cultural and recreational objectives all within the limits set by natural dynamics. It covers the full cycle of information collection, planning, decision making, management and monitoring of implementation in the coastal zone.	▪ Dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones; ▪ ICZM seeks over the long-term, to balance environment, socio-economic, cultural and recreational objectives; ▪ ICZM Reduces ecosystem degradation; and also conserves and maintains existing ecosystems from potential climate change impacts; ▪ Manages / protects coastal resources in a sustainable way; ▪ Involvement of local communities or stakeholders participation in decision of sustainable environmental management.

2	Flood early Warning System (FWS)	The FWS is a means of detecting threatening events in advance to help protect lives and properties. In general, it aims to reducing the degree of casualty that could be caused by coastal flooding through alerting the public in advance to take appropriate actions (Response). Such service is highly important and needed in developing countries such as Liberia where coastal flooding is increasingly becoming a national concern.	▪ In general, it aims to reducing the degree of casualty that could be caused by coastal flooding through alerting the public in advance to take appropriate actions (Response); ▪ Detects threatening events in advance to help protect lives and properties. ▪ The data collected (Tidal, Meteorological, wave, river, wind and etc.) for the said service could also be used for mitigation and sustainable environmental planning. ▪ Promotes human capacity building as a FWS requires technical training of monitoring and forecasting ▪ Creation of job opportunities.
3	Rock/ Amor Revetment	A revetment is a sloped seaward structure of hard engineering option which protects against erosion caused by wave action, storm surge and tidal effects. It is often built with armour boulders (rocks), concrete or other durable materials to protect a scarp, shoreline, embankment or sand dune against erosion.	▪ Protects against erosion caused by wave action, storm surge and tidal effects; ▪ Shall easily be widely adapted nationally due to the availability of ideal rocks quarries; ▪ Protects and fixe the boundary between the sea and land; these actions protect and assist in maintaining the landward environment; ▪ Not very expensive and has low maintenance cost as compare to other hard defence systems.

<u>MCA results of technology prioritization for the coastal zone:</u>

Performance Matrix												
	Costs		Benefits									
			Economic			Social			Environmental			Climate related
	capital	Maintenance & Oppetation	Source of Income / livelihood	Promote Tourisme	Increased industrialization /Applicability	Job opportunity.	Protect lives & Property	Gender sensitive	Environmental Sustainability	Conservation of Ecosystem	Vulnerability & Risks reduction	Resilient to Sea level Rise (SLR)
Integrated Coastal Zone Management : ICZM	66	73	82	82	81	84	74	85	87	89	91	88
Beach Nourishment	94	73	27	52	19	21	21	60	44	16	32	37
Flood Warning System (FWS)	89	92	90	63	66	51	52	61	84	34	35	6
Groynes	80	55	20	49	18	5	34	18	77	64	65	67
Rocks Revetment	83	78	71	47	25	60	55	66	86	83	85	86
Sea-walls	87	63	61	27	21	9	4	2	51	28	77	69
Coastal Wetland Protection and Restoration	69	76	53	2	5	12	5	21	61	75	66	33
Restoration of coastal vegetation (Coconut trees , Mangroves)	40	15	90	23	30	75	51	10	60	30	30	22
Monitoring Coastal Erosion and flood												
Artificial Sand Dunes and Dune Rehabilitation												

Figure 7: MCA Performance Matrix

Scoring Matrix (Criteria scores vary from 0 to 100)													
	Costs		Benefits										
			Economic			Social			Environmental			Climate related	
	Capital	Maintenance & Oppetation	Source of Income / livelihood	Promote Tourisme	Increased industrialization /Applicability	Job Opportunity	Protect lives & Property	Gender sensitive	Environmental Sustainability	Conservaton of Ecosystem	Vulnerability & Risks reduction	Resilient to Sea level Rise (SLR)	
Integrated Coastal Zone Management : ICZM	66	73	82	82	81	84	74	85	87	89	91	88	
Beach Nourishment	94	73	27	52	19	21	21	60	44	16	32	37	
Flood Warning System (FWS)	89	92	90	63	66	51	52	61	84	34	35	6	
Groynes	80	55	20	49	18	5	34	18	77	64	65	67	
Rocks Revetment	83	78	71	47	25	60	55	66	86	83	85	86	
Sea-walls	87	63	61	27	21	9	4	2	51	28	77	69	
Coastal Wetland Protection and Restoration	69	76	53	2	5	12	5	21	61	75	66	33	
Restoration of coastal vegetation (Coconut trees , Mangroves)	40	15	90	23	30	75	51	10	60	30	30	22	
Monitoring Coastal Erosion and flood													
Artificial Sand Dunes and Dune Rehabilitation													
Criterion weight	0.15	0.05	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1

Figure 8: MCA Scoring Matrix

Decision Matrix: Weighted Scores														
	Costs		Benefits										Total score	Rank
			Economic			Social			Environmental			Climate related		
	Capital	Maintenance & Oppetation	Source of Income / livelihood	Promote Tourisme	Increased industrialization /Applicability	Job Opportunity	Protect lives & Property	Gender sensitive	Environmental Sustainability	Conservaton of Ecosystem	Vulnerability & Risks reduction	Resilient to Sea level Rise (SLR)		
Integrated Coastal Zone Management : ICZM	9.9	3.65	6.56	6.56	6.48	6.72	5.92	6.8	6.96	7.12	7.28	7.04	80.99	1
Beach Nourishment	14.1	3.65	2.16	4.16	1.52	1.68	1.68	4.8	3.52	1.28	2.56	2.96	44.07	
Flood Warning System (FWS)	13.35	4.6	7.2	5.04	5.28	4.08	4.16	4.88	6.72	2.72	2.8	0.48	61.31	3
Groynes	12	2.75	1.6	3.92	1.44	0.4	2.72	1.44	6.16	5.12	5.2	5.36	48.11	
Rocks Revetment	12.45	3.9	5.68	3.76	2	4.8	4.4	5.28	6.88	6.64	6.8	6.88	69.47	2
Sea-walls	13.05	3.15	4.88	2.16	1.68	0.72	0.32	0.16	4.08	2.24	6.16	5.52	44.12	
Coastal Wetland Protection and Restoration	10.35	3.8	4.24	0.16	0.4	0.96	0.4	1.68	4.88	6	5.28	2.64	40.79	
Restoration of coastal vegetation (Coconut trees , Mangroves)	6	0.75	7.2	1.84	2.4	6	4.08	0.8	4.8	2.4	2.4	1.76	40.43	
Monitoring Coastal Erosion and flood														
Artificial Sand Dunes and Dune Rehabilitation														
Criterion weight	0.15	0.05	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1	

Figure 9: MCA Decision Matrix; Weighted Scores

Chapter 4: Summary and Conclusion

As the coastal zone is one of the nation's greatest environmental and economic assets; it is to be noted that more than 70% of Liberia’s population lives within its coastal areas of about 580 km long (DAI 2008). However, the direct impacts of coastal erosion, flood, saline/ seawater intrusion into fresh drinking waters, sea level rise and etc. in the coastal zone have become some of the alarming climate change risks currently affecting coastal cities and communities along majority of Liberia’s coastline for which this report presents the TNA process for sectors selection and technology prioritization for adaptation of the above climate change impacts in the coastal zone.

The coastal zone was selected by multi-stakeholders as one of the three sectors for adaptation and mitigation for Liberia’s TNA process due to the ongoing disasters, risks and level of vulnerability to lives and properties along the nation’s coastline. Having selected the coastal zone, a technical working group consisting of professionals from different institutions (government ministries & agencies, private, NGOs , businesses, and etc.), headed by the national coastal zone consultant *(Mr. E.Tenesee Wilson)* was formed to identify and prioritize technology options based on the technology’s potential to reduce vulnerability to climate change, and social, economic, and environmental benefits. The technology prioritization process was carried out using the TNA’s “Multi Criteria Analysis (MCA)” for which three (3) technologies were prioritized/ selected to be used for the TNA project in the coastal zone of Liberia to mitigate and adapt to the above mentioned climate change impacts. The three technologies to be used are:

a. Integrated Coastal Zone Management (ICZM);
b. Flood early Warning System (FWS), and
c. Armour or Rocks Revetment.

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Annex I: Factsheets of the ten (10) Technologies

Table 6*:* *TFS -1;* Integrated Coastal Zone Management (ICZM)

Sector	Coastal Zone
Technology's Name	Integrated Coastal Zone Management (ICZM)
Description	The concept of ICZM was born in 1992 during the Earth Summit of Rio de Janeiro (Agenda 21, Chapter 17). ICZM is a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. The ICZM seeks over the long-term, to balance environment, socio-economic, cultural and recreational objectives; all within the limits set by natural dynamics. It covers the full cycle of information collection, planning, decision making, management and monitoring of implementation. The ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM has been established and currently functioning in many developed countries with numerous success stories. ICZM could as well be vital to the adaptation or mitigation process of coastal risks and vulnerabilities in many developing nationals as Liberia.
Environmental benefits	Environmentally, ➢ ICZM Reduces ecosystem degradation; ➢ Conserves and maintains existing ecosystems from potential climate change impacts; ➢ Manages / protects coastal resources in a sustainable way; ➢ Involvement of local communities or stakeholders participation in decision of sustainable environmental management.
Socio-economic benefits	Some socio-economic benefits to implementing ICZM: ➢ Multi tasks and conflicts solving in using sustainable and efficient coastal management; ➢ Most appropriate measure to address short and most importantly long-term challenges in coastal zones; ➢ Protecting lives and properties by reducing coastal vulnerabilities and risks; ➢ Enhancing living standards in many developing countries through sustainable developmental projects; ➢ Many coastal adaptation and mitigation projects are easily supported by international donors through an established ICZM; and this creates jobs for local communities.

Institutional and Organizational Requirement	➢ Establishment of communication and coordination strategies; involvement and participation of relevant authorities; ➢ Potential vision and action plan for the area should clearly be defined; ➢ Local representation and consultation from community based level; ➢ Technical /operational guidance and support (logistics & financial) should be given great attention.
Costs/ Financial requirements	Capital cost for ICZM technically surrounds "*Implementation* and *technology application costs* "; The cost of deployment depends on the cost of information collection, database construction in coastal areas and the cost of training, capacity building, organizational structure and coordination costs, and hiring of experts. The costs of adapting to climate change in most coastal zones depend on the location which greatly influences the cost of technology needed to conduct field assessment or data collection and adaptation methods. Due to a number of situations including geographical location, expertise, equipment and etc.: Scenarios of a specific coastal technology is needed in a developing country as cost may vary in function of many issues.
Country Status and Implementation/ Application potential	ICZM is attracting more attention of national natural resources and environmental managers in Liberia (EPA, Ministry of Mines & Energy, UNDP, USAID and etc.). Currently in Liberia, the ministry of Mines & Energy is increasing efforts to establish an ICZM, but the major challenges surrounding the success of ICZM is to have: passion, well defined vision and developed strategies and action plan, established databases and information systems management, expertise, support, proper coordination and involvement of all relevant local and national stakeholders' participation from the community level.
Barriers	➢ Full participation of relevant stakeholders and public into the ICZM process and its Implementation; ➢ The successful functioning of ICZM requires comprehensive management between local and central authorities (Stakeholders), national and international cooperation and coordination between public and private sectors. ➢ Financial and logistical support to properly execute/ realize the ICZM concept. ➢ It also requires a well professional interdisciplinary knowledge as ecology, geology, marine biodiversity, technology, politic, engineering, environment laws etc.
Acceptability	The concept of ICZM is highly needed in Liberia as flood and coastal

To local stakeholders	erosion risks and vulnerabilities have become a national emergency. Local communities are presently calling on national government to workout modality and put in adaptation / mitigation mechanisms.

Table 7: TFS- 2: Flood early Warning System (FWS)

Sector	Coastal Zone
Technology's Name	Flood early Warning System (FWS)
Adaptation category	Accommodation Approach
Description	A flood warning system is a means of detecting threatening events in advance to help protect lives and properties. In general, it aims to reducing the degree of casualty that could be caused by coastal flooding through alerting the public in advance to take appropriate actions (Response). Such service is highly important and needed in developing countries such as Liberia where coastal flooding is increasingly becoming a national concern. This technology functions in a way that; once an event exceeds a given threshold, a warning will be issued. Said message is likely to be disseminated to the 'at risk' population. To achieve a successful FWS, a constant monitoring of meteorological and tidal conditions is required in conjunction with river and coastal flood forecasting models.
Environmental benefits	• The data collected (Tidal, Meteorological, wave, river, wind and etc.) for the said service could also be used for mitigation and sustainable environmental planning. • A frequent high risk flood occurrence environment could be used or reserved for different purpose rather than residential.
Socio-economic benefits	• Implementing a well-functional flood warning system aims to mitigate the impacts of coastal flooding on lives and properties; • It promotes human capacity building as a FWS requires technical training of monitoring and forecasting • Creation of job opportunities.
Institutional and Organizational Requirement	Institutions of flood warning services vary widely between countries and depend on the scale of the overall system. To facilitate the establishment of a FWS costs, the following services, and coordination could be provided by nation government: • Detection of rainfall, river level, tidal level, wind, wave and other monitoring equipment or agencies;

	• Dissemination of information to the 'at-risk' population to flood; • Establishing and supporting an emergency response team, An effective FWS requires cooperation between different agencies, such as the government, relief agencies and local communities. As such, this approach has both technical and organizational challenges.
Costs/ Financial requirements	The costs of implementing flood warning systems are expected to differ widely, depending on the level of sophistication of monitoring and forecasting technologies. In developing countries, meteorological observations are frequently made using basic methods, which may include ground-based methods and weather balloon observations, coupled with limited computing. In these cases, annual running costs are expected to be in the hundreds of thousands of pounds. It is also not unusual for flood warning schemes in developing countries to be heavily funded by international civil society organizations (UK POST, 2005). FWS may be seen as a cost-effective means of mitigating flood hazards as compare to some hard engineering defence methods. <u>Factors influencing the cost of implementing a FWS</u> • Extent of meteorological monitoring network • Cost of sourcing meteorological data • Set up costs of warning dissemination system and its degree of sophistication • Training and employment costs of meteorological data analysts • Cost of associated measures: *Provision of flood shelters;* *Creation of evacuation routes;* *Awareness raising;* *Training of emergency services.*
Country Status and Implementation/ Application potential	As it seems to be challenging in establishing a well functional flood warning service in developing countries as Liberia, This has however, been achieved in some developing countries such as Bangladesh (Haque, 1995; Mirza et al., 2005) and Vietnam (Pilarczyk & Nuoi, 2010) with the help of foreign organizations who can supply information and real-time data on weather patterns (Haque, 1995). Therefore, this is possible and applicable in Liberia with a well-coordinated system and cooperation of relevant government agencies or ministries and even with the help of foreign organizational partnership.
Barriers/ Challenges	Some major challenges faced by developing countries in having a well functional FWS: • The approach of FWS requires a significant volume of detailed information to be collected and analyzed in order to detect

	accurate flood threats; • FWS needs significant investment in equipment and training; • Timely dissemination of information or alert to the *"at-risk"* population in order to take necessary actions; • Well trained and equipped emergency response team. • Constant monitoring of meteorological and tidal conditions in conjunction with river and coastal flood forecasting models.

Table 8*:* *TFS- 3:* Armor or Rocks Revetment

Technology's name	Armour or Rocks Revetment
Sector	Coastal Zone
Description	A revetment is a sloped seaward structure of hard engineering option which protects against erosion caused by wave action, storm surge and tidal effects. It is often built with armour boulders (rocks), concrete or other durable materials to protect a scarp, shoreline, embankment or sand dune against erosion. As coastal erosion vulnerabilities and risks have become a national concern in Liberia, the application and adaptation of rocks revetment option is necessary and could easily be widely adapted nationally due to the availability of ideal rocks quarries.
Socio-economic benefit	Rock revetments are attractive to tourists, therefore they promote coastal tourism. Revetments could also be used for recreational activities. The implementation of such shall provide job opportunities for local coastal community and as well, for coastal engineers, geologists, geo-technicians and etc.
Environment benefit	Revetments provide protection against shoreline change and related coastal flooding, and fixe the boundary between the sea and land; these actions protect and assist in maintaining the landward environment. Rocks revetments also minimize the destructive and hazardous risks to coastal ecosystem, vegetation, sand dunes and important infrastructures. They also prevent coastlines which are subjected to erosion, high wave impact and coastal flooding from related degradation. Said technology provides high level of security which can favour the development of coastal communities. Revetments constructed with rocks promote the formation of coral reefs and attract many coastal species. This option of coastal defence helps to stabilize

	the beach environment and in general, reduces coastal vulnerability to climate change impacts.
Institutional and organizational requirements	An effective and successful revetment construction project requires cooperation between different agencies, ministries. As such, this technology requires both technical and organizational expertise. Therefore, the following are essential: ➢ Establishment of communication and coordination strategies for the involvement and participation of relevant authorities; ➢ Assist with data (wave, tidal, topographic and etc.) from government related coastal, marine and environmental ministries or agencies for construction purpose; ➢ Technical /operational guidance and support (logistics & financial) should be given great attention. ➢ Coordinate and support the effectiveness of implementation; ➢ Provide training for capacity building of a specific component; ➢ Assist with available related equipment and etc.
Costs and Financial Requirement	Construction costs or rocks revetments vary significantly and can escalate rapidly. Factors influencing implementation price include proximity of quarry, availability of required size range, demand, and site access, complexity of design and length of revetment to be constructed. Therefore, revetment projects should typically include and consider the above mentioned and the following items. • Preliminaries field assessment, • Mobilization of plant and equipment; • Site establishment; survey; construction management plans; • Materials supply and equipment: armours, geotextile, core, trucks, excavators, front-end loader, crane and etc. • Survey work and etc. (Swan River Trust, 2009) With the above mentioned, it is understood that estimating or attaching a price to a revetment construction is difficult.
Maintenance Activities	The life duration of revetments depends on the initial design conditions and maintenance regime. A properly designed and constructed rocks revetment should have a design life of more than 25 years, with a modest degree of maintenance. Generally, a significant maintenance exercise would be required in the first few years of construction as the structure settles down. Regular inspection is required following severe storms and floods activities. These would also determine the ongoing maintenance requirements. Maintenance of well designed and constructed revetments should be limited to occasional repacking and replacement of armour.

Table 9: *TFS- 4:* Artificial Sand Dunes and Dune Rehabilitation

Sector	Coastal Zone
Technology Name	Artificial Sand Dunes and Dune Rehabilitation
Description	Artificial sand dunes are soft engineered structures created to mimic the functioning of natural dunes. Dunes rehabilitation refers to restoration of natural or artificial degraded dunes to optimize coastal protection benefits. Artificial sand dunes construction and dune rehabilitation are technologies aimed to reducing both coastal erosion and flooding in adjacent coastal low lands. Artificial dunes are often used in conjunction with beach nourishment and can be reinforce using geotextile or vegetation planting to help stabilize the respective dune. This technology can be use on existing beaches, beaches built through nourishment, existing dunes, undeveloped land, undeveloped portions of developed areas, and in fully developed areas that have been purchased for restoration. The purpose of this technology is to prevent further coastal erosion and flooding. As well as helping to dissipate incoming wave energy. As such, dunes are able to supply sediment to the beach when it is needed in times of erosion, or store it when it is not (French, 2001). This is achieved by introducing large quantities of beach material to the coastal sediment budget from an external sediment source (Morton, 2004).
Environmental Benefits	Promotes safe interface between the sea and land, limits negative effects on landscape and restores a degree of natural character to places that had naturally occurring dunes complexes before development. Conservation of diverse, unique biodiversity and landscapes, and provides valuable coastal habitats for many highly specialized plants and animals.
Socio-Economic Benefits	This approach is achievable with minimal cost and if managed properly, it can provide high degree of protection against coastal flooding and erosion. Such option will provide employment opportunities for women, students and small/medium machinery establishment. It creates a path way to multiples management objectives, such as habitat protection, public access to environmental and recreational resources and hazard mitigation. Job opportunities will also be provided to coastal engineers etc. The width of the beach shall also attract recreational activities that could promote coastal eco-tourism.
In country status of Technology	This form of coastal protection for erosion and minimization of flooding is acceptable for coastal zone management and has been applied in many

	countries. But however, there is no nationally known approach of artificial sand dune construction and dune rehabilitation project that has been implemented or adapted as a coastal defence approach in Liberia. Nevertheless, there is a locally noticed method applied by private coastal properties owners, by using or placing sand bags against dunes for stabilization purposes. The bags are not geotextile, therefore depreciate shortly. This method has not been widely applied or adapted as an approach.
Adaption/Application potential	This technology has been implemented in both developed and developing countries such as: USA, Vietnam…etc.; as such, it can be applicable in some major vulnerable coastal cities in Liberia. As such measure promotes gender balance, women, youth groups; local coastal community leaders could easily apply this approach.
Barriers & Disadvantages	➢ Despite being a natural feature of many sandy coastlines, dunes also represent or appears to be a barrier to beach access; ➢ Blocks Sea view for habitat and small/medium establishments, as a result, dunes are not properly constructed at a required height; ➢ Potential degradation due to recreational activities; ➢ Limited maintenance or management by local community.
Costs / Financial requirement	Dunes restoration and rehabilitation is highly applied in developed and developing countries. As such, it appears that the construction and rehabilitation of dunes is reasonable. However, the financial requirements vary by countries and depend on some of the follow: ➢ Availability and quantity of beach materials (sand) to be used; ➢ Transport distance of beach materials to project site; ➢ Availability of equipment to be used (bulldozers, trucks, and other traditional equipment for dunes construction and restoration); ➢ Topography of project site for sand dunes and rehabilitation of dunes ➢ Access to project site (beach).

Table 10: *TFS* **-** *5*: Beach Nourishment

Sector	Coastal Zone
Technology Name	Beach Nourishment
Description	It is a soft engineering approach to coastal protection which involves the artificial addition of sediment (sand) of suitable quality to a beach area that has a sediment deficit. This form of coastal protection by adding beach material rebuilds and maintains the beach at a width which helps in reducing the rate of beach recession or shoreline change (French, 2001). Beach Nourishment is often used in conjunction with artificial dune creation. It could also be used to complement a hard engineering approach such as sea-walls, revetments, dykes, etc. Nourishment approach is mainly used on sandy beaches like those in Liberia where we are suggesting the application of said technology. The logic behind beach nourishment is to turn an eroding, reflective beach into a wider, dissipative beach. As well as helping to dissipate incoming wave energy; beach nourishment addresses a sediment deficit: the underlying cause of erosion. This is achieved by introducing large quantities of beach material to the coastal sediment budget from an external sediment source (Morton, 2004).
Environmental Benefits	Beach nourishment is a soft structural measure that doesn't disturb coastal natural processes or have adverse impacts on neighbouring areas in contrast to most hard coastal engineering approach. It is also possible to provide ecological benefits through beach nourishment such as provision of shelter and additional breeding sites for turtles, sea birds and other endangered and ecologically important organisms (Dean, 2002).
Socio-Economic Benefits	This project will provide employment opportunities to those who are involved in the sand mining business/ industry, dredging and operation of respective machinery during beach nourishment. Job opportunities will also be provided to coastal engineers, geologists and geo-technicians. Wider beaches after beach nourishment often attract tourist, as such, coastal community will make living through activities related to coastal tourism. It has a great potential to create or promote socio-recreational activities (Nicholls et al., 2007b). Such project provides access to future sustainable coastal management.
In country status of Technology	From national coastal documents read, there is no report of beach nourishment project that has been implemented as a coastal defence

	approach in the country (Liberia). Currently (2019), there are ongoing studies by CDR International to review the applicability of this technology in appropriate vulnerable coastal areas. As such, West-Point community seems favourable.
Application potential	Stakeholders and decision makers in Liberia could minimize the implementation cost of beach nourishment by utilizing the sediments from dredging project for coastal structures such as the Freeport of Monrovia. This is applicable to smaller / shorter coastline closer to the Freeport of Monrovia, such as the West-Point community or Kru-Town. Highly applicable in West-point in conjunction with a well-placed rock groyne at the river to prevent long shore transport of nourishment materials.
Barriers	➢ High cost of implementation and maintenance. ➢ Beach nourishment last for about 4 to 6 years depending on the quantity and quality of nourishment materials and most importantly, the coastal dynamics of the area to be applied. ➢ Availability of equipment and material to be used: offshore dredging or inland mining of sand and etc. ➢ External beach nourishment materials may lead to negative impacts to the local environment and ecosystem.
Capital Costs	Beach nourishment is highly applied in developed countries. As such, from research of implemented projects' documents, it appears that the costs of nourishment vary by countries and greatly depends on: ➢ Availability of beach materials to be used; ➢ Transport distance of beach materials to nourishment site; ➢ Availability of equipment to be used (dredge, trucks, pipeline, etc.) ➢ Quantity of materials for nourishment ➢ Topography of site to be nourished According to Linham et al. (2010), the unit costs of beach nourishment in developed countries were shown to typically vary from US$ 3-15/m3 (at 2009 price levels) where dredge sites were available locally. In developing countries, costs would be expected to be similar or possibly higher, due to their less developed coastal engineering industry. The most important determinant of nourishment costs appears to be the transport distance for the beach material

Table 11: TFS-7: Groynes

Sector	Coastal Zone
Technology Name	Groynes
Description	Groynes are coastal defence structures built perpendicularly to the shoreline of the coast (or river) to minimize longshore drift and trap sediment. By doing so, they help to build and stabilize the beach environment. They are generally solid, durable structures and are considered as a hard-engineering protection measure to reduce coastal erosion hazard. Groynes can be constructed from wide variety of materials where rock is often used in recent years as construction material. However, wooden groynes, steel groynes, rubble-mound, and sand filled bag groynes, or groynes made of concrete elements can also be used. Rocks groynes have greater energy dissipation characteristics which are more suitable in relation to the surrounding coastal landscapes and environment. This is suitable for Liberia due to the high wave energy condition and also the availability of rocks that can withstand coastal water condition (senility, wave and tidal conditions and etc). The ideal groyne field allows sediment to accumulate and eventually bypass the buried groynes without causing significant down-drift erosion. However, this is rarely achieved due to a lack of data on wave climate and long-shore sediment transport rates (Davis Jr and Fitzgerald 2004).
Environmental Benefits	• Rocks groynes promote the formation of coral reef; • Rocks groynes attract many coastal species; • Reduction of coastal vulnerability to climate change impacts; • Nationally promote rocks quarry industry; • It traps sediments from longshore drift, building-up of beach in size and maintains coastal ecosystem; • Help to stabilize the beach environment. • Reduce coastal erosion on beach significantly.
Socio-Economic Benefits	Rock groynes are attractive to tourists, therefore promote coastal tourism. The implementation of such shall provide job opportunities for local coastal community and as well, for coastal engineers, geologists, geo-technicians and etc. It traps sediment, leading to beach widening, reduced erosion and greater wave energy dissipation which overall, reduces the risk of coastal erosion and inundation to lives and properties along the beach. Serves as a robust structure (if designed and maintained properly) that can be used for societal / recreational activities.

	Low maintenance costs
In country status of Technology	In Liberia, there are few groynes that have been constructed at some sea ports serving as a break-water. But the traditional coastal defence groynes are yet to be adapted national. Traditional rock groynes in conjunction /attached to a rock revetment could easily be adapted and widely implement across the country due to the availability of suitable rocks.
Adaption potential or Implementation Need	Rock groynes are highly applicable and feasible along many beaches in Liberia. As it reduces the rate of beach degradation, it promotes the formation of coral reef which could be important to the economy of local community and etc. Rock groynes could be one of the easily adapted hard engineering measures for coastal erosion in Liberia, due to the availability of ideal rocks and reasonable cost of implementation in regards to other hard engineering structures.
Barriers and Disadvantages	➢ They trap sand that is flowing to the neighbouring beach and cause down-drift beach erosion; ➢ Many groynes are required along the vulnerable beach with about 50 to 100 meters groyne field (spacing) in regards to the coastal dynamics; ➢ Each groyne could have a length of about 50 to 100+ linear meters depending on the condition of the area (wave, long-shore current, bathymetry, and etc.); ➢ The availability of required equipment and materials to be used; ➢ Availability of required local experts and etc.
Costs	Groynes are highly applied in developed countries. As such, from research of implemented projects, it appears that the cost of a groyne vary in respect to the length, width, groyne field, depth of water and etc. Other factors influencing the cost of a groyne project are: ➢ Availability of ideal rocks that meet construction standards; ➢ Transport distance of groynes' materials (rocks, timbers, etc.) to project's site; ➢ Access to project's site; ➢ Availability of proper equipment to be used; ➢ Quantity of materials for groyne construction.
Institutional Requirement	• Provide capacity and implementation modality, and coordination; • Provide data on wave climate and long-shore sediment transport rates; • Regulate river sand mining and introduce internally applied

	standards of such; • Prohibit beach sand mining in all coastal counties; • Provide training for locals that shall gradually have the required expertise for future groynes or coastal defence projects; • Provide coastal engineering and management courses in public universities for capacity building; • Conduct regular periodic awareness and sensitization of coastal zone protection /management.

Table 12: TFS - 8: Monitoring of Coastal Erosion and Flooding

Sector	Coastal Zone
Technology Name	Monitoring of Coastal Erosion and Flooding
Description	Coastal erosion and flooding have become a major issue for coastal communities and ecosystems around the world. Coastlines are immensely subject to natural and anthropogenic influence such as: global warming related sea level rise, storms and changing land-use patterns. Due to higher waves and storms resulting to intensification of shoreline erosion contribute to leaving large areas completely submerged. Coastal environments are experiencing more frequent and destructive flooding, degraded water quality and smaller/fewer beaches. Currently in Liberia, the impacts of coastal erosion and related flooding have degraded lot of beaches leading to the destruction of coastal properties, infrastructures, environment and etc. These impacts have resulted to the high level of vulnerability of coastal communities and risk to livelihoods. Therefore monitoring shoreline change that results from coastal erosion and related flooding is essential to the protection of lives and properties along the coastline and related coastal communities. This forms an important aspect of Integrated Coastal Zone Management (ICZM). The implementation and adaptation of this technology require a variety of hardware and software equipments for implementation. The use of remote sensing, integrated with GIS in conjunction with DSAS and other erosion models contribute extensively to the understanding of coastal dynamics. Monitoring is an important aspect of adaptation because it helps to assess whether adaptation has achieved its goals and can also yield new insights and information which give rise to strategy adjustments as appropriate (Klein et al., 2001).
Environmental Benefits	This technology helps to save lives and as well, informs vulnerable coastal communities to take appropriate actions that will reduce the

	impacts on homes, businesses, infrastructure, ecosystem, and etc. from coastal erosion and related flooding.
Socio-Economic Benefits	• The adaptation of said approach will provide job opportunities to coastal communities, coastal engineers, GIS specialists and etc. • This promotes scientific research, coastal data collection and contributes to capacity building; • Encourages and protects investment in coastal areas; • Promotes development of coastal zones.
Adaptation/ Application potential	This approach can be achieved and adapted in Liberia through and by support to an appropriate ministry, agency, university research programs, private consultancy, coastal community group and etc. Coastal erosion and related flooding are major climate change impacts affecting coastal countries, including Liberia. Therefore, it is highly important to monitor these related coastal climate change vulnerabilities and risks in Liberia to reduce their impacts to the society and environment.
Barriers & Disadvantages	➢ Limited required expertise to easily be implemented; ➢ Associated cost and financial requirement for implementation and maintenance; ➢ Relies on investment in hardware, automated processes and software; and requires professional skills and capability of the monitoring network; ➢ Environmental changes, in particular climate change, may have an effect on strategic monitoring method; ➢ Impact of population growth in coastal areas.
Costs / Financial Requirement	The implementation of this technology highly depends on equipment, data, DGPS, software, computers, coastal models and etc. Hence, the financial requirement for implementation is in accordance to the needed equipment for effective monitoring.
Institutional Requirement	• Coordinate and support the effectiveness of coastal monitoring; • Assist with data collection from government related coastal, marine and environmental ministries or agencies; • Provide training for capacity building of a specific component; • Assist with available related equipment and etc.

Table 13: TFS – 9: Restoration / planting of coastal vegetation (Coconut trees, Mangroves)

<table>
<tr><td>Sector</td><td>Coastal Zone</td></tr>
<tr><td>Technology Name</td><td>Restoration / planting of coastal vegetation (Coconut trees, Mangroves)</td></tr>
<tr><td>Description</td><td>Coastal vegetation is a technology accepted worldwide for the prevention of coastal erosion and for ecosystem restoration. It is considered as a soft defence measure against coastal erosion, inundation, dunes degradation and etc. It may usually form part of bigger coastal projects such as dunes and coastal wetland restoration for which it could be associated.

There are several methods or techniques used for restoration of coastal vegetation planting; some are:

• Seedling
• Native stand transplant or nursery grown transplant

The above mentioned methods can be implemented by using hand planting techniques, mostly implemented on small areas and steep slopes. Larger and flatter areas may be planted using slightly modified tractor-drawn trans-planters.

The use of native vegetation in dune construction/ stabilization and repairs is critical to the success of any coastal shoreline and dune restoration project. Selection of plant species is of great importance when restoring vegetation. Coastal vegetation is self-tolerant with dense root system, and effective at holding onto the sand, thus diminishing rate of dune erosion or degradation caused by waves and winds.</td></tr>
<tr><td>Environmental Benefits</td><td>➢ Enhances the restoration of biodiversity through the promotion of habitat, specific targeted species;

➢ The selected Coastal vegetation with dense root system is very effective at holding onto the sand and reduces the rate of dune erosion or degradation caused by waves or winds actions.
➢ It provides protection against coastal erosion, inundation and will minimize the negative impacts on beaches from natural phenomena.

➢ Improves stability of dunes and ecosystem, biodiversity and also provide food and shelter for coastal wildlife.</td></tr>
<tr><td>Socio-Economic Benefits</td><td>➢ Minimizes risk of coastal inundation and erosion of coastal environments and reduces risk of properties to be damaged by coastal hazards (coastal erosion, coastal landslide, inundation, etc.).
➢ Increases income to persons involved in coastal re-vegetation (agriculturalists) programs, eco-tourism, coastal resource management and recreational activities.</td></tr>
</table>

	➢ Provides research opportunities for students, such as improvement of awareness; the importance of conservation, management, and restoration of coastal vegetation. ➢ Improvement of scientific knowledge on the sensitivity and ecological importance of coastal vegetation. ➢ Implementation of said project will provide employment opportunities to persons involved in coastal zone management sector, nurseries management, and ecotourism centres and most importantly, it is feasible by women; therefore, promote gender balance empowerment.
In country status of Technology	In Liberia, planting of coconut trees along the beach has been traditionally practiced but on a minimum scale, mostly in the interior part of the country. As restoration of coastal vegetation, planting of coconut trees is been practiced on a minimum scale, this could easily be adapted on an industrial scale across coastal cities within the country.
Adaption or Application potential	The technology can be implemented in conjunction with dune restoration and other hard defence measures such as revetments. This technology can be widely adapted across many coastal cities in Liberia as it can be done by local community groups: Women's group, youth and etc. With not much complication to be implemented, this could easily be accepted by local community leaders, stakeholders and others.
Barriers and Disadvantages	• Required lot of people for the planting of the trees; • Required many trees to be planted; • Cost of feeding, planting of specific vegetation, training of personnel and providing security during implementation; • Insufficient socio-political commitment for coastal resource conservation and management. • Little or no support to coastal communities to initiate a sustainable management, protection or conservation of coastal vegetation.

Costs/ Financial Requirement	Restoration of coastal vegetation has been successfully implemented in many developed and developing countries worldwide (Mauritius, Sri Lanka, USA and etc.). This technology is less costly as it relates to other technologies. The costs vary by country; the cost also strongly depends on: ➢ The type of trees/ vegetation and quantity to be planted; ➢ In country availability of the specific vegetation for replanting; ➢ Training of implementers and large scale adaption; ➢ Payment of staff to carry out the restoration; ➢ Travelling and transportation costs for on site assessment and relocation of plants. ➢ Allowances for person involved in transplanting and taking care of the transplant at the initial state;
Institutional requirement	• Conduct regular and periodic public awareness on the importance of maintaining and protecting coastal vegetation. • Identify vulnerable coastal areas for adaption of coastal vegetation restoration. Coordinate knowledgeable public institutions, women's groups, youth groups, NGO and other qualified individuals for the implementation of said technology.

Table 14: TFS – 9: Seawall (SW)

Sector	Coastal Zone
Technology Name	Seawall (SW)
Description	Seawalls are in general massive concrete structures, because they are designed to resist the full force of incoming waves. A seawall is a form of hard engineering structure built on the beach parallel to the shoreline. It could be large or small, high or low in function of the wave and tidal conditions of the area. It is constructed of a wide range of materials including concrete, wood, plastic, rock, construction rubble, steel, aluminium, sand bags and etc. (Pilkey et. Al., 1996). They are use to prevent coastlines which are subjected to erosion, high wave impact and coastal flooding. This form of coastal defence (SW), aims to protect upland infrastructure from flooding, wave impacts, and over topping; It also helps to hold land fill (bluff, shoreline) in place.
Environmental Benefits	Seawalls provide a high degree of protection against coastal flooding and

	erosion and fixe the boundary between the sea and land; these actions protect and assist in maintaining the landward environment. SWs minimize the destructive and hazardous risks to coastal ecosystem, vegetation & sand dunes, important infrastructure or buildings and businesses located along the shoreline. They also prevent coastlines which are subjected to erosion, high wave impact and coastal flooding from related degradation It provides high level of security which can favour the development of the hinterland.
Socio-Economic Benefits	➢ Educational and scientific development ➢ The implementation of a seawall project shall provide employment to professional individuals (coastal, marine, geotechnical engineers, equipment renters and etc.) involved in coastal sector. ➢ The construction of SW has a lower space requirement than other coastal defence structures such as dikes. ➢ Promotes new establishment/settlements within said coastal belt due to minimum risk to infrastructure from coastal erosion and inundation; this condition shall present self-employment opportunities within the area. ➢ Most coastal defence structures are attractive when well designed; this therefore promotes coastal tourism and services.
In country status of Technology	After an extensive research and revision of many national coastal related documents (1st National communication and etc.), there wasn't an official account of a seawall project that has been implemented as a coastal defence techniques or approach Nationally. Although, there are reports of some quick impact projects of different technique against coastal erosion, (*eg. Buchanan- Grand Bassa Co., Hotel Africa- Monrovia, D-Twe High school- Monrovia*). Currently (2019), there is an ongoing hard engineering option of coastal defence (revetment) along the New Kru-Town's coastline. Said project is being implemented by the Ministry of Mines & Energy (MME) and supported by the GEF through the UNDP.
In Country Need of the Seawall Technology	In Liberia, as coastal erosion has become a major impact of many climate change risks affecting livelihoods, Seawall could be one of the coastal defence technologies to be applied where environmentally, socially and in general, scientifically applicable to protect lives and properties.
Barriers	➢ Expensive to build (when it comes to implementation and maintenance). ➢ Life span up to 50 years with periodic maintenance. ➢ The availability of expertise, materials, appropriate equipment for the construction.

Implementation Costs	Seawall is highly applied in developed countries and some developing countries. A study by Linham et al. (2010) indicates that the unit cost of constructing 1 km of vertical seawall is in the range of US$ 4 to 27.5 million. The study found seawall costs for around ten countries. As such, the implementation cost of seawall varies due to numerous factors, such as: ➢ Design height which is a major factor affecting costs per unit, length of seawall and etc. ➢ Maintenance costs are another significant and ongoing expense when a hard defence of concrete structure option is selected.
Institutional Requirement	➢ Stakeholders and decision makers in Liberia could minimize the implementation cost of seawalls by partnering or benefiting from climate change international donor funds. ➢ Awareness and capacity building ➢ Identifying and prioritizing most vulnerable communities based on social, economic, environmental and gender factors.

Table 15: TFS – 10: Coastal Wetland Protection and Restoration

Sector	Coastal Zoon
Technology Name	Coastal Wetland Protection and Restoration
Description	Coastal Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion management. Therefore, coastal wetland restoration should be promoted in many developing countries as it provides new habitats and many environmental benefits. The most commonly restored wetland ecosystems for coastal protection are salt marshes and mangroves. These habitats 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 stabilize shore sediments, thus reducing erosion (USACE, 1989). Restoration is required in Liberia because many of our wetlands have become increasingly degraded through both natural and human activities. 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 and also the environmental policies and lifestyle of said area.
Environmental benefits	In terms of climate change adaptation in the coastal zone, wetland restoration reduces the 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 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 (White et al., 2010). This option also helps reduce wetlands losses as a result of climate change.
Socio-Economic benefits	Wetland restoration /creation can bring about various economic, social, and environmental benefits to local communities. For example, it has the capacity to improve the productivity of coastal waters for fishing. Coastal Wetlands are a sustainable source of timber, fuel and fibre. Programs of wetland restoration have a great potential to create jobs for local coastal communities, and contribute toward local sustainable development. This can also create opportunities for eco-tourism and increase recreational opportunities. In so doing, wetland restoration is a growing concern in developing countries such as Liberia, regarding wetland loss and the associated loss of ecosystem functions such as habitat provision, food production and water quality improvement.
Institutional and Organizational Requirements	At a local level, proactive measures can be implemented to ensure wetland habitats are maintained and used in a sustainable manner. This will preserve habitats into the future and reduce or even avoid the cost of restoration and planting schemes. By preventing wetland loss or degradation, it is also possible to avoid the many potential problems encountered in the course of wetland restoration efforts (NRC, 1992).
Costs/ Financial Requirement	As '*wetland*' refers to a diverse range of habitats, it is difficult to give accurate cost estimates. Different types of wetland will require different restorative measures with varying costs and labour requirement depending on the location (Country), type and size of wetland to be restored, expertise availability, degree of degradation and etc. However, a cost and benefit of mangrove restoration study in Vietnam by Tri et al. (1998), estimated planting, capital and recurrent costs at approximately US$41 per hectare of mangrove planted, at 2009 prices. Said cost includes planting costs and the cost of thinning from year six onwards. From other project documents, restoring wetlands costs US$3,500 to $80,000 per acre (http://www.bnl.gov/erd/peconic/factsheet/wetlands.pdf) At Mon Choisy, Mauritius, mangrove plantation has been estimated at Rs5,640/m; this amount is approximately US$ 170/m (Adaptation Fund project, pp54-55) Clearly, estimating the costs of wetland restoration is complex and depends on a large number of factors. The cost of individual projects should be calculated on a case-by-case basis.
Implementation/ Application potential	It is less expensive and more aesthetically pleasing than some engineering solutions; the approach is likely to find broader public support for implementation in a developing country as Liberia with many coastal environmental concerns

	(coastal erosion, flooding, wetland degradation and etc.) Wetland restoration meets multiple management objectives such as habitat protection, public access to environmental and recreational resources and hazard mitigation. The technology has been in use for past 20-30 years worldwide. The market for learning from successful implementation and management restoration and protection projects exists worldwide.
Barriers	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 defence. A desire to improve wetland habitats also needs to exist before the strategy can go ahead. This may involve public awareness of the benefits of wetland restoration and recreation, the lack of which is itself one of the most significant barriers.
Acceptability to local stakeholders	Without additional understanding, local communities might oppose the restoration of coastal wetlands, seeing it as a loss of land with development potential.

Annex II: List of stakeholders on Coastal Technical Working Group

Table 16: Technical working group on coastal zone (TWG)

Stakeholders Information of Technology Prioritization :(TWG)				
No.	**Names**	**Gender/Sex**	**Institution/ Organization**	**Contact**
1	Johnson S. Willabo Jr.	M	Asst. Minister: Ministry of mines & Energy (MME)	Johnson.willabo@yahoo.com
2	Dennis K. Yeberth	M	Community youth Empowerment Representative	koffa1908@gmail.com
3	Anthony A. Yokie	M	NaFAA	ayokie2017@gmail.com
4	J. Josiah N. Domah	M	MACSP- EPA Focal-point	josiahdomah@gmail.com
5	Atriana N. Sirleaf	F	Ministry of Internal Affairs (MIA)	
6	Victor B. Smith	M	Alliance Consulting Engineers (ACE)	vicbo.jarezan@aol.com
7	Ruth M. Toe	F	University of Liberia (UL)	ruthmtoe@gmail.com
8	Helen Sempn-Howard	F	Ministry of Commerce and Industry (MoCI)	
9	Emmett K-Max Paye	F	Initiative for Youth and Children Advancement (I-IYOCA)	
10	Arthur Becker	M	Environmental Protection Agency (EPA)	abecker@epa.gov.lr
11	E.Tenesee Wilson	M	National Consultant, Coastal Zone	e.teneseew@gmail.com