



Republic of The Gambia

**TECHNOLOGY NEEDS
ASSESSMENT REPORT – Adaptation
Technologies**

7 September 2016



Report I: Adaptation Technology Needs Assessment

This publication is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP DTU Partnership (UDP) in collaboration with the Regional Centre Energy Research Centre, University of Cape Town. The views expressed in this publication are those of the authors and do not necessarily reflect the views of UNEP DTU Partnership, UNEP or the University of Cape Town. We regret any errors or omissions that may have been unwittingly made. This publication may be reproduced in whole or in part and in any form for educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. No use of this publication may be made for resale or any other commercial purpose whatsoever without prior permission in writing from the UNEP DTU Partnership.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

- 1.1 National circumstances
- 1.2 National strategies
- 1.3 Policies and actions related to climate change
- 1.4 Vulnerability assessments in The Gambia
- 1.5 Sector selection
 - 1.5.1 Process of Sector Selection
 - 1.5.2 An Overview of current climate and expected climate change

CHAPTER 2: INSTITUTIONAL ARRANGEMENT AND STAKEHOLDER INVOLVEMENT

- 2.1 National Institutions involved in Climate Change
- 2.2 The TNA Project bodies
 - 2.2.1. Project Steering Committee
 - 2.2.2. National TNA Team
 - 2.2.3. TNA Coordinator
 - 2.2.4. National Consultants/Experts
 - 2.2.5. Sectoral Adaptation Technologies Workgroups
- 2.3 Stakeholder Engagement Process followed in the TNA – Overall assessment

CHAPTER 3: TECHNOLOGY PRIORITISATION FOR THE AGRICULTURE SECTOR

- 3.1 Key Climate Change Vulnerabilities in Agriculture Sector
- 3.2 Decision context
- 3.3 Overview of Existing Technologies in Agriculture Sector
- 3.4 Adaptation Technology Options for Agriculture Sector
- 3.5 Criteria and process of technology prioritisation
- 3.6 Results of technology prioritisation
 - 3.6.1 Conservation Agriculture
 - 3.6.2 Tidal Irrigation
 - 3.6.3 Aquaculture and Fish Farming

CHAPTER 4: TECHNOLOGY PRIORITISATION FOR COASTAL ZONE SECTOR

- 4.1 Key Climate Change Vulnerabilities in Coastal Resources Sector
- 4.2 Decision context
- 4.3 Overview of Existing Technologies in Coastal Resources Sector
- 4.4 Adaptation Technology Options for Coastal Resources Sector
- 4.5 Criteria and process of technology prioritisation
- 4.6 Results of technology prioritisation for the Coastal Resources sector
 - 4.6.1 Sustainable Sand Management
 - 4.6.2 Breakwater systems
 - 4.6.3 Groyne Systems

CHAPTER 5: TECHNOLOGY PRIORITISATION FOR WATER SECTOR

- 5.1 Key Climate Change Vulnerabilities in Water Resources Sector
- 5.2 Decision context
- 5.3 Overview of Existing Technologies in Agriculture Sector
- 5.4 Adaptation Technology Options for Water Resources Sector
- 5.5 Criteria and process of technology prioritisation
- 5.6 Results of technology prioritisation
 - 5.6.1 Water Conservation
 - 5.6.2 Relocation of Water Points
 - 5.6.3 Aquifer Recharge

CHAPTER 6: SUMMARY AND CONCLUSIONS

- 6.1 The TNA process

- 6.2 Criteria utilized in the process
- 6.3 Results of the Technology Prioritization
- 6.4 Recommendations and Way Forward

List of Figures

- Figure 1: Projected of Mean Annual Temperature by Three General Circulation Models
- Figure 2: Maps of Projected Mean Annual Temperature ($^{\circ}\text{C}$) of The Gambia to 2100
- Figure 3: Projected Potential Evapotranspiration of The Gambia
- Figure 4: Projected Mean Annual Rainfall of The Gambia
- Figure 5: Maps of Projected Annual Rainfall (mm) of The Gambia to 2100
- Figure 6: Simulated Dry Matter (Kg/ha) Production in Maize
- Figure 7: Simulated Dry Matter (Kg/ha) Production in Early Millet
- Figure 8: Simulated Dry Matter (Kg/ha) Production for Late Millet
- Figure 9: Simulated Dry Matter Production for Groundnuts
- Figure 10: Simulated grain dry weight (kg/ha) of irrigated rice at Kuntaur (The Gambia).
- Figure 11: NARI Research Programmes and relevant technologies
- Figure 12: National Agricultural Research Institute (NARI) Farmer Field School
- Figure 13: The Agro-Ecological Village Approach (Gomez et al, 2013)
- Figure 14: Orthophoto Map (contours in metres) of the Capital City of Banjul
- Figure 15a: Interlocking Sea Wall
- Figure 15b: Sea wall or Bulkhead similar to one at Kairaba Beach Hotel
- Figure 16a: Groynes made out of wooden planks
- Figure 16b: Groynes made out of rocks and concrete
- Figure 17a: Revetments constructed out of Boulders
- Figure 17b: Armorloc Concrete Revetment
- Figure 18a: Open and Sheltered Coastal Zone of The Gambia
- Figure 18b: An attempt to protect the Senegambia Beach Hotel against acute erosion
- Figure 18c: Kololi Beach Area in 2002 before Nourishment
- Figure 18d: 100metre-wide nourished Kololi Beach Area in 2003
- Figure 18e: Kololi Beach Area in 2010 – 7 years after nourishment
- Figure 18f: Kololi Beach Area back to where it was before nourishment
- Figure 19a: The capital city of Banjul is less than 1metre above water
- Figure 19b: Mangrove Swamps serve as Fish Spawning Grounds
- Figure 20: Examples of Breakwater Systems
- Figure 21a: Beach Nourishment device
- Figure 21b: Aerial view of Kairaba and Senegambia seafront
- Figure 22: Hand dug well fitted with hand pump for a population of about 500 persons
- Figure 23a: Borehole drilling equipment for water supply
- Figure 23b: Solar pumping system for rural water supply
- Figure 23c: Before construction of water supply system
- Figure 23d: After construction of water supply system
- Figure 23e: Infrastructure for livestock watering
- Figure 23f: Trained Water Committee responsible for the management of village water facility
- Figure 24: Rainwater Harvesting from Runoff in Northern Togo
- Figure 25: Common sight of repairs of leakage due to aging infrastructure

List of Tables

Table 1: Membership of the TNA Project Steering Committee

Table 2: List of Members of the Adaptation Technologies Working Group

Table 3: Identified adaptation options for the Agriculture sector

Table 4: List of criteria, their categories and the allocated weights for the Agriculture sector

Table 5: Prioritized and Ranked Technologies for the Agriculture Sector

Table 6: Criteria, their categories and the allocated weights for the Coastal Resources sector

Table 7: Prioritized and Ranked Technologies for the Coastal Resources Sector

Table 8: Similar projects implemented in the country

Table 9: Similar projects implemented in the country

Table 10: Long List of climate change adaptation for the Water Resources Sector

Table 11: Criteria, their categories and the allocated weights for the Water Resources sector

Report I: Technology Needs Assessment Report

Executive Summary

The TNA project is being implemented to provide targeted financial and technical support to assist The Gambia carry out environmentally sound Technology Needs Assessments (TNA) within the framework of Article 4.5 of the UNFCCC. The Gambia is using the support (tools and methodologies) provided by the Technical Assistants (TAs) from UDP and other partners to identify priority and vulnerable sectors and establish the mitigation and adaptation technologies needed for implementation of the climate change response strategies and activities. Relevant TNA institutional structure is put in place and the capabilities of key national actors are built and/or strengthened to enable them to perform the tasks that include the understanding of the trends in the current and future climate, determining the level of vulnerability of the national economy and the various sectors to climate change, as well as the prioritized adaptation strategies and actions, determining the adaptation technologies needed to implement the adaptation actions, identifying and adapting the methodologies and tools to prioritize the technologies and conduct the prioritization of the adaptation technologies, assessment of barriers that need to be overcome for diffusion and application of the acceptable technologies. This TNA report will be followed by the assessment barriers to the access, adopt and implement the identified technologies and then develop the national Technology Action Plans (TAPs) for prioritized technologies that support adaptation to climate change, and are consistent with national sustainable development objectives.

Economically, The Gambia is ranked among the least developed countries (LDCs). In 2014, the country's nominal GDP was US\$864 million. Taxes accounted for 84% of government revenue (excluding grants and loans). The National Climate Change Policy represents The Gambia's determined response to the interlinked climate threats to sustainable development, well-being and ecological integrity. The goal of the Policy is, by 2025, to guide the mainstreaming of climate change into planning, budgetary and other decision-making, and implementation of responses in The Gambia through effective institutional mechanisms, coordinated financial resources, and enhanced human resources capacity.

The Gambia has developed and published climate change strategic reports which suggest that under the projected climate change, The Gambia will be warmer (current mean annual temperature increases 0.3°C in 2010 to about 3.9°C in 2100), and drier (mean annual rainfall decreases from about 1% in 2010 to about 54% in 2100; potential evapotranspiration increases by about 10%). Overall, food security is threatened and ecosystem productivity and services in The Gambia will be poor under climate change. Adaptation options and technologies have been identified and some of these are under implementation.

The UDP Technical Mission to The Gambia in March and April 2015 initiated the engagement of stakeholders in the TNA process. During the TNA Project Inception workshop, agreement was reached to work on Agriculture, Coastal Resources and Water Resources sectors in assessing adaptation technologies. The National TNA Committee constituted two thematic (mitigation and adaptation) working groups to engage relevant stakeholders in the TNA process.

The Adaptation Sectoral Working Group includes persons drawn from public and private sector departments. Series of consultative meetings and trainings of the members of the Working Group were conducted at the national level. The TNA Adaptation Consultant also participated in the regional training workshop held in Arusha Tanzania in June 2015. The stakeholder engagement is expected to continue beyond the production of the Report of the Technology Needs Assessment of The Gambia. Stakeholders will be continuously engaged in the production of the rest of deliverables of the TNA Project including a report on the Barrier Analysis and the Technology Action Plan (TAP).

The Adaptation Sectoral Working Group worked with the National Consultant to conduct the technology prioritization for the three sectors of Agriculture, Coastal Resources and Water Resources. The prioritization process included the review of key national climate change strategic documents that include the First and Second National Communications (NATCOM) and the National Adaptation Plan of Action

(NAPA). Key climate change vulnerabilities and ongoing and planned adaptation activities for the three sectors were analysed and taken into account in technology prioritisation for the selected sectors.

For the Agriculture Sector, productivity of all food crops (corn and millet) is projected to decrease as the climate warms but the productivity of groundnuts (peanuts), a cash crop, is projected to increase. Food insecurity is expected to be enhanced. Ongoing and planned climate change adaptation projects to reduce vulnerabilities and meet adaptation needs in the Agriculture sector of The Gambia include:

1. The GoTG/GCF/UNEP Large-scale ecosystem-based adaptation (EbA) which is a cost-effective and low-risk approach expected to effect a transformational change in rural Gambia by increasing crop and livestock productivity, the supply of resources from forest ecosystems and conservation of biodiversity under climate change conditions;
2. The GOTG/GEF/UNDP/UNEP LDCF climate change early warning system is strengthening climate information and early warning systems, increasing national and sectoral adaptive capacities and promoting the transfer and adoption of adaptation technologies;
3. The Agriculture for economic growth and food security/nutrition project under Phase I (2016 to 2017) will contribute to sustainable growth in the agriculture sector and reduce food insecurity and malnutrition; and
4. The GoTG/GEF/FAO Project entitled “Adapting Agriculture to Climate Change in The Gambia” has the objective to promote sustainable and diversified livelihood strategies for reducing the impacts of climate variability and change in agriculture and livestock sector;

Existing agricultural and food security technologies being developed, disseminated and implemented in The Gambia include irrigation (tidal, drip and sprinkler), aquaculture, water harvesting from surface runoff, crop breeding, and livestock breeding. Tidal irrigation systems are common in the upper reaches of the River Gambia with fresh water throughout the year. Drip and Sprinkler irrigations are applied at smaller scales compared to tidal irrigations. Conservation agriculture (CA) is an agricultural system involving a suit of adaptation technologies that aim at soil and water conservation, nutrient improvement and enhanced production. Zero tillage, as a component of Conservative Agriculture, was applied in The Gambia on a relatively small scale in the 1980s and 1990s. The National Agricultural Research Institute (NARI) supports and facilitates transfer of these technologies to stakeholders.

The National Adaptation Consultant and stakeholders initially identified a long list of 27 climate change adaptation technologies which they reduced to eight high priority adaptation technologies (Tidal Irrigation; Drip Irrigation; Sprinkler Irrigation; Food Processing, Preservation and storage; Aquaculture; Crop Breeding; Livestock Breeding and Feed Enhancement; and Conservation Agriculture) for the Agriculture sector. The National Adaptation Consultant and stakeholders developed and used technology factsheets in selecting the technologies for further analysis and prioritisation using Multi-Criteria Analysis (MCA). Applications of defined criteria, units and weights to the identified adaptation technology options resulted in Conservation Agriculture as the highest priority adaptation technology for the Agriculture sector. This was followed by Tidal Irrigation and Aquaculture.

For the coastal resources sector, sea level rise in The Gambia is projected to be significantly higher than the average ??? IPCC predictions. Impacts of sea level rise include the inundation of about 92 km² of the coastal zone, by 2100, including the city of Banjul. The mangrove systems on St. Mary’s Island and Kombo St. Mary and the strand plains from Barra to Buniadu Point will be lost. Ecological impacts of beach erosion include the loss of nesting grounds for green turtles, and submergence of diverse habitats and ecosystems. Ongoing and planned climate change adaptation projects to reduce vulnerabilities and meet adaptation needs in the Coastal Resources sector of The Gambia include:

- a) GOTG/GEF/UNDP LDCF Coastal Resilience Project which is expected to improve coastal defenses and enhance capacities of coastal communities;
- b) GOTG/WB/AfDB Pilot Programme for Climate Resilience (PPCR) is expected to climate proof urban and peri-urban infrastructure in the Brikama and Greater Banjul Areas of The Gambia;

Existing adaptation technologies in Coastal Resources Sector include sea walls, groynes, and revetments. Offshore breakwaters, which are used to break the waves further offshore and therefore reduce their erosive power are being constructed in some sectors of the coastline. To address adaptation in the coastal zone of The Gambia, a list of climate change adaptation options and corresponding technologies to implement the options were identified by the National Adaptation Consultant in collaboration with the stakeholders. These were ranked using the MCA software using agreed criteria, units and weights to the adaptation technology options. Sustainable sand management was the highest ranked adaptation technology option followed by breakwater systems and Groyne systems.

Water resources in The Gambia include surface and groundwater systems. With changing climate, a 3% reduction in groundwater recharge, by the year 2075 is projected; increased PET is projected and freshwater recharge downstream will reduce and cause hyper-salinity in mangrove and other wetlands along the river's estuary and coastal zone. Hyper-salinity in rice growing swamp areas could negatively impact the food production and livelihoods associated with rice production. Under the projected rise in mean sea level, it is observed that maximum saline intrusion length increases by a mere 40 m/year. Heavy precipitation events will cause increased flooding and associated health risks such as contamination of drinking water supplies and the creation of conditions conducive to pathogens.

Ongoing and planned climate change adaptation projects to reduce vulnerabilities and meet adaptation needs in the Water Resources sector of The Gambia include:

- a) GoTG/AfDB Water Sector Reform Project (2010 to 2015) was supported by the Africa Water Facility and supports the establishment of IWRM in The Gambia in line with the National Water Policy and the IWRM Roadmap, as well as develop the legal and institutional arrangements for the implementation of the water policy.
- b) GOTG/WB/AfDB Pilot Programme for Climate Resilience (PPCR) has a water supply, sanitation and waste management component is expected to construct and manage climate change resilient water supply infrastructure (standpipes, boreholes, wells, etc.).

Existing adaptation options and technologies include water conservation which is a composite of technologies that include reduction in water losses from leakage, decrease in water demand, increasing water use efficiency, and effective management of water supply systems using efficient institutions such as Village Water Committees (VWCs). Water harvesting from rooftops and surface runoff is applied in The Gambia and it is simply the collection and distribution of natural rain water for domestic and irrigation applications. The surface runoff water harvesting technology is useful in increasing livestock productivity, expanding horticulture, increasing the availability of protein from fish and reducing conflicts due to transboundary movement of animals in search of water and pasture.

To prioritize climate change adaptation technologies in the water sector, the Adaptation Working Group and National Consultant identified criteria, units and weights and inputted them in the MCA tool. Water Conservation was ranked the highest priority followed by Relocation of Water Points and Aquifer Recharge.

CHAPTER 1 INTRODUCTION

Through this TNA project, The Gambia is being supported to carry out Technology Needs Assessments (TNA) within the framework of Article 4.5 of the UNFCCC. The process involves the identification and prioritization of technologies as well as barriers to their implementation, and development plans to enable the technology diffusion and action plans. The existing national economy, sectoral strategies and policies related to technological innovation, adaptation to climate change and development priorities have been assessed.

1.1 National circumstances

The economy of The Gambia is largely dependent on agriculture, which accounted for around 25% of gross domestic product (GDP) over the period 1994-2013 and which provides employment for 70% of the labour force. The industrial sector (about 15% of GDP over the same period) consists mostly of construction and agro-processing activities. Services accounted for 60% of GDP, with trade and transport, and communications being its two largest components. Tourism is The Gambia's primary foreign-exchange earner (WB, 2015).

Service industries, which account for 58% of GDP, include finance, retail/wholesale, transportation and real estate services (GOTG, 2007, CBG 2015). Financial services, comprising banking, insurance and related services, account for 10.7% of GDP, employ 5% of the work force and undergird virtually all economic activities. Retail trade, which accounts for slightly less than a quarter of the Gambian economy, is the biggest benefactor of the financial services industry.

In the past decade, The Gambia's commitment to poverty reduction, coupled with an annual GDP growth rate averaging 6% from 2003-2006, has resulted in poverty rates falling from 58% in 2003 to 48.4% in 2010 (MoFEA, 2011). However, extreme poverty remains widespread, with nearly 40% of the population existing on less than US\$1 per person per day (GBS, 2010). Income poverty remains concentrated in rural areas, especially among households headed by subsistence farmers and unskilled workers. Children and adults aged 65 years and above show higher poverty rates (HIS, 2010).

The Gambia is ranked among the least developed countries (LDCs). In 2014, the country's nominal GDP was GMD37,339 million, i.e., US\$864 million based on the end-of-year exchange rate of GMD43.2 per US Dollar in 2014¹. Taxes accounted for 84% of government revenue (excluding grants and loans). Approximately 20% of total revenues, five percentage points higher than grant receipts, was allocated to debt servicing, contributing to short- and long-run financial vulnerability (ProPAG, 2013).

Within this context, the Programme for Accelerated Growth and Employment (PAGE) 2012-2015 sets out various strategies for accelerating and sustaining economic growth, including through improving and modernising infrastructure, strengthening human capital, improving governance and fighting corruption, and reinforcing social cohesion. National priorities revolve around sustainably exploiting agriculture, tourism, infrastructure and other natural resources; and consolidating and

¹ http://usd.fxexchangerate.com/gmd-2014_12_31-exchange-rates-history.html

extending the gains registered in the health and education sectors. Climate change is included within the PAGE as a cross-cutting issue, together with environment, disaster risk reduction and gender equality.

Social successes include achieving the education MDG target for net enrolment in primary education and literacy rate among 15-24 year olds, and significantly reducing the malaria burden. Nevertheless, the national context remains one of relative social and economic fragility. Existing widespread poverty is coupled with multi-dimensional social vulnerability, as well as gaps in the provision of social protection (GoTG, 2015c). Four key issues affect people's livelihoods: lack of productive employment, low returns on labour, inadequate support for entrepreneurship development, and harvest failures among farming households.

The state of the ecological resource base is critical for the resilience of the country, due to the direct reliance of the economy and of many people's livelihoods on the natural biophysical systems. Biodiversity is impressive in The Gambia, due to the combination of its geographical position and the central presence of the River Gambia (GOTG, 2014). However, habitat destruction as a result of urbanization, cultivation, uncontrolled burning, and wood utilization has led to degradation of the ecosystem services and to local extinction of many well-known species. The terrestrial surface of The Gambia in the past was covered by dense forest, estimated at 43% of the total land area of the country (GOTG, 2011). However, comparison of the most recent forest inventory initiatives conducted against earlier records reveals a declining forest cover from 505,300 hectares (ha) in 1981/82 to 423,000 hectares in the 2009/2010 inventory. Human population growth coupled with the decline in annual average rainfall of 25-30%, high consumption rates and inappropriate technologies used in land and forest management continue to be a major driving force for environmental and natural resource degradation. Rangeland systems cover about 40% of the total land area and are characterised by poor drainage and low soil fertility; thus they are susceptible to loss of productivity due to over-exploitation and climate effects.

1.2 National strategies

The Programme for Accelerated Growth and Employment (PAGE)

The Government of The Gambia is committed to reducing poverty and improving the well-being of its population. This commitment is driven by the Government's long-term strategy, Vision2020, which is being executed through a series of medium-term development plans since 1994.

The Programme for Accelerated Growth and Employment (PAGE) is The Gambia's medium-term development strategy and investment programme for 2012 to 2015. It is based on Vision 2020 and various sector strategies and it is the main interface between the Government and The Gambia's development partners. The focus of PAGE is to accelerate pro-poor growth and generate employment.

Public Service Reform Strategy

In The Gambia, there is a serious concern that the human and institutional capacities to formulate policies, design and implement programmes and deliver quality services to meet Government's development priorities are limited and eroding as well (PMO, 2007). The overall goal of the public sector strategy is to reform and restructure the public sector into a lean, affordable and efficient service that is able to formulate sound gender sensitive and equitable public policy and to ensure that it can effectively implement the policies. The key objectives of the strategy include (a) the strengthening of institutional capacity for policy formulation, human resources development, coordination and monitoring of the public sector management and programmes, (b) improving the governance and management of the Civil Service to ensure transparency and accountability and promote ethical values and standards in order to create a merit-based system within the Public Service and (c) improvement of the Civil Service remuneration package so as to retain highly trained and professional staff within the Civil Service.

The Agriculture Sector Strategies

The key strategic objectives for the Agriculture and Natural Resources (ANR) sector by 2015 (MOA, 2009) are (a) improved and sustainable measurable levels of food and nutrition security in the country in general and vulnerable populations in particular; (b) a commercialized ANR sector ensuring measurable competitive, efficient, and sustainable food and agricultural value chains, and linkages to markets; and (c) institutions (public and private) in the sector are strengthened, and providing needed services, strong and enabling environment, and reducing vulnerability in food and nutrition security.

The Coastal Resources Strategies

The medium term development framework of The Gambia, Vision 2020, has identified the major environmental challenges facing the country as land degradation, loss of forest cover, loss of biodiversity, coastal erosion, waste management and reducing GHG emissions and associated impacts of climate change. The coastal region of The Gambia provides valuable natural resources and supports a rich variety of biological diversity as well as tourism which is estimated to contribute about 12% to the GDP. Erosion, largely due to climate change induced sea level rise and extractions of beach sand for construction and other purposes, has recently intensified along the coast posing a serious threat to the tourism infrastructure, wildlife habitat and the livelihood of communities living along the coast. On average, erosion rates measure about 1 to 2 meters/year, amounting to about 200,000 to 300,000 m³/yr (ICAM Plan 1998). Recent studies indicate that, in some places such as Bijilo beach area the rate is up to 4m/year (Haskoning, 2000). The destruction of the coastline not only destroys wildlife habitat but poses a serious threat to the hotels and other recreation centres in the tourism area. In the coastal zone the implementation of the coastal protection works from July 2003 to April 2004 helped minimize/halt the coastal erosion. Some of the lost coastal areas recovered through soft and hard engineering interventions (Beach nourishment, construction of groins, revetments). Presently, a Coastal Zone Management Policy and Guidelines are to be formulated for the sustainable exploitation/utilization of the coastal zone and its resources.

The recent policy shift from 'institution-based' to 'community – based' approach in the management and sustainable use of natural resources allows local communities a greater say and

ownership over the resources in and around their communities. A major area of opportunity is the participation of private sector and development partners in environmental management to promote and /or support environmentally –friendly enterprises in the form of ‘Green Jobs’. It is strategic to asses of socio-economic, financial as well as environmental factors impeding the development of such business and a strategy developed to address these constraints and promote their development. A special target will be the promotion of green industries. Such a strategy will effectively link environmental protection with employment creation and poverty reduction. Finally there is the need to strengthen public awareness on environmental issues in order to bring about attitudinal changes and greater commitment at individual and community levels to the cause of environmental protection and promote popular initiatives in addressing environmental challenges.

The Water Sector Strategies

The Water Strategy provides the National Water Policy with implementation guidance, technical direction and momentum to develop the water sector further. It employs international best practices and applies the Integrated Water Resources Management (IWRM) principles through actions, that include but not limited to (a) collection and dissemination of data and information relevant to the assessment of surface and groundwater resources and determine sustainable yield; (b) improvement of the provision of potable water supplies in urban, peri-urban and rural areas through the application of decentralisation principles which ensures responsibility delegated to the lowest appropriate level; (c) assurance that the demands from agriculture, fisheries, navigation, industry, tourism and recreation are met in a sustainable manner, and (d) assurance that the best available technologies are available and applied through an on-going programme of research and development.

Climate Change Strategic documents:

The Gambia signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and ratified it in 1994. Since its ratification of the Convention, The Gambia has taken very important steps at the national, regional and global levels to face the challenges climate change. Various studies have been conducted and their findings have been disseminated widely. These strategic documents include:

1. GOTG/GEF/UNEP Greenhouse Gas Inventory of 1997;
2. GOTG/USA Climate Change Vulnerability Assessment of The Gambia in 1997;
3. GOTG/GEF/UNDP National Capacity Self-Assessment of 2004;
4. GOTG/GEF/UNDP Initial National Communication (INC)of the Republic of The Gambia to the UNFCCC in 2003;
5. GOTG/GEF/UNEP National Adaptation Program of Action (NAPA) in 2007;
6. GOTG/AfDB Nationally Appropriate Mitigation Actions (NAMA) in 2011;
7. GOTG/AfDB Nationally Appropriate Mitigation Actions in Agriculture(AfricNAMA,2013); and
8. GOTG/GEF/UNEP Second National Communication (SNC) of the Republic of The Gambia to the UNFCCC in 2013.

The National Communication reports have been prepared to give a summary of the country situation with regards to climate change. It provides an overview of the national circumstances, an

inventory of greenhouse gas emissions, and impacts of climate change on key sectors of the national economy and provides information on the potential responses (mitigation and adaptation) to climate change.

The NAPA covers three broad sectors namely, the economic sector, the natural resources sector and the social sector. It critically re-examines the role of climate on societal and natural systems and is implemented through institutional arrangements at the central, regional and community levels. The NAPA is in line with other development frameworks such as the the second Poverty Reduction Strategy Paper (PRSP II), the UNDP Country Program Document (CPD) and the Millennium Development Goals (MDGs). The PRSP II provides a framework for medium to long term socioeconomic development. The long term goal of PRSP II is to eradicate poverty by significantly increasing national incomes through stable economic growth and reducing income and non-income inequalities through several poverty interventions. The NAPA has a common objective with the MDG's; to provide food security and enhance sustainable livelihoods of those engaged in Agriculture, Livestock and Fisheries sectors (NAPA,2007).

1.3 Policies and actions related to climate change

The National Climate Change Policy represents The Gambia's determined response to the interlinked climate threats to sustainable development, well-being and ecological integrity set out in the preceding sections. The Policy defines the following Vision and Goal for The Gambia (GoTG/MoECCFWW, 2016):

VISION:

Within a generation, achieve a climate-resilient society, through systems and strategies that mainstream climate change, disaster risk reduction, gender and environmental management, for sustainable social, political and economic development.

GOAL:

The goal of the Policy is, by 2025, to guide the mainstreaming of climate change into planning, budgetary and other decision-making, and implementation of responses in The Gambia through effective institutional mechanisms, coordinated financial resources, and enhanced human resources capacity.

In order to achieve the goal and move towards the vision of this Policy, the following key policy objectives will be pursued:

1. Advance the **understanding, capacity and social empowerment** of all Gambians so that they can adequately respond to climate change.
2. Ensure adequate **climate change research for informed decision making**, and promote timely **access to climate information and early warning** of climate risks.
3. Put in place **sound and equitable adaptation and mitigation measures** that promote effective management of ecosystems and biodiversity, reduce vulnerability to climate

change impacts, and reduce greenhouse gas emissions, to achieve sustainable low-carbon socio-economic development.

4. Effectively integrate climate change into all sectors and across all scales, through **mainstreaming climate risks and opportunities into national and sectoral frameworks**, and through **effective policy coordination and implementation**.
5. **Build the resilience of communities to climate change impacts and ensure health and welfare** through participatory, equitable and pro-poor approaches to climate change, that emphasize the meaningful inclusion of women and vulnerable groups.
6. **Integrate community-based adaptation with ecosystem-based approaches to strengthen people's adaptive capacities** and develop more climate-resilient livelihoods, by investing in sustainable natural resource management initiatives.
7. **Coordinate international and national financial resource mobilization** to address climate change by mainstreaming climate finance readiness and identifying, developing and promoting innovative financing mechanisms.

The Agriculture and Natural Resources (ANR) Policy: The ANR sector is notable for its high potential and comparative advantage in the country's economy to achieve food security, increase incomes, and generate employment and foreign exchange earnings. These strengths have positioned the sector to be central to the country's economic growth and development, and as such, it has been identified as a prime sector for investments to reduce poverty, meet the Vision 2020 objectives and the MDG 1 "...to halve the proportion of the poor and those who suffer from hunger." The sector houses the largest human resource base in the economy, who are largely poor, and who use low inputs and traditional technologies just for subsistence. There is therefore the urgent need to transform the ANR sector from its present subsistence state to a modern and market-oriented sector for it to contribute significantly to national food security. A clear policy framework would be necessary to provide a logical basis for the planning, support to, and management of the ANR sector for the contributions it should make towards poverty reduction and economic growth. Unfortunately, the ANR sector does not possess any such governance instrument presently. With the country's second Poverty Reduction Strategy (PRS II) now at the start of its implementation, the establishment of such a framework for the sector is therefore compelling.

The National Water Policy: is the planning and management framework for providing the people of The Gambia with secure water resources. The overarching Policy objectives are the establishment of a manageable and inclusive water resources framework based on IWRM principles, and the promotion of an enabling environment for conservation of the resources and preservation of the environment for future generations, maintenance of an equitable balance between universal access to water supplies and the needs of individual users, strengthening and development of the human capital and build the economy of the country, and negotiation and discharge of international responsibilities in a spirit of good will and cooperation.

Other Relevant Policies include:

- **The Gender Policy** is an integral part of the national development objectives to enhance the overall government strategy of growth through poverty eradication. Gender being a

crosscutting issue, the policy is developed along six thematic areas embracing the government's priority development concerns. It specifically covers the priority gender issues that must be mainstreamed in development policies and programmes (MoWA, 2009)². This is to address the existing gender imbalances and ensure sustained and sustainable socio-economic development. The policy covers gender in relation to Education, Health, Sustainable Livelihoods Development, Good Governance, Human Rights and Poverty Reduction and Economic Empowerment.

- **The Decentralization Policy** which is explicitly expressed in the Constitution of the Second Republic of The Gambia and Vision 2020, both of which stress the need for decentralization in order to harness popular participation at the grassroots level in national development. The decentralization policy objectives include (a) building adequate capacity at Local Government levels to facilitate absorption of the respective required competencies, (b) capacity building for decentralized development planning, awareness creation, and the sound financial base necessary to implement the programme, and (c) the setting up of a coordinating, monitoring and evaluation mechanism. These policy objectives aim at promoting the direct participation of the population in the management of their own affairs, and the promotion of a spatially integrated approach to local development.
- **The Disaster Management Policy** has the overall objective of building safe and resilient communities by enhancing the use of and access to knowledge and information in disaster prevention and management at all levels of society. The Policy is designed to (a) promote the incorporation of disaster prevention and management education in both the formal and non formal educational systems, (b) pay particular attention to the gender dimension of disaster management, (c) make a case for a culture of prevention to be taught in schools, emphasized by the media and vigorously pursued by disaster management agencies, and (d) promote the incorporation of indigenous knowledge into early warning systems and disaster response initiatives.
- **The National Social Protection Policy 2015-2025 (NSPP)** of The Gambia was designed to contribute towards the alleviation of poverty and vulnerability in the country, in line with the Government of The Gambia's Vision 2020 and the 2012-2015 Programme for Accelerated Growth and Employment (PAGE). The NSPP defines a comprehensive and cross-cutting social protection reform agenda and proposes a set of priority actions to guide the gradual establishment of a coherent social protection system in The Gambia. The long-term vision (2015-2025) for social protection is to establish, by 2025, an inclusive, integrated and comprehensive social protection system that will effectively provide protective, preventative, promotive and transformative measures to safeguard the lives of all poor and vulnerable groups in The Gambia and contribute to broader human development, greater economic productivity and inclusive growth. The objective of the NSPP is to facilitate the reform of the national social protection system by ensuring more efficient and effective use of resources, strengthened management and administrative systems, and greater progress towards a more inclusive form of social protection that makes

basic income and social services available to The Gambia's poorest and most vulnerable people – gradually expanding access to the entire population.

- **The Health policy** is in line with the Vision 2020 and the Millennium Development Goals (MDGs), the Gambia National Development Strategy (2012-2015) and Investment Program – The Program for Accelerated Growth and Employment (PAGE) – which will lead to achievement of all the Millennium Development Goals, especially those related to health; accomplishing a three-quarters decline in maternal mortality and a two-thirds decline in mortality among children under five; halting and reversing the spread of HIV/AIDS and to provide special assistance to AIDS orphans; and putting the country on a strong footing to attaining the Vision of the President. The theme, *“health is wealth”*, which is the current philosophy which The Gambia's national health policy is hinged upon becomes a reality only when a healthy population can contribute to improved productivity, increased GDP and sustained economic growth and overall ensure social equilibrium. Hence the slogan *“A Healthy population is a Wealthy population”*.
- **The Trade Policy** has the objective to maintain an open and liberal trading environment and to better integrate The Gambia into the global economy. It also aims at providing direction for trade activities as well as to ensure trade mainstreaming in the productive sectors to make its contribution to the attainment of national goals of growth, development, and poverty reduction. The Trade policy will regulate the environment for trade and also produce results that will make the country's trade grow and be more competitive.

1.4 Vulnerability assessments in The Gambia

The Gambia has developed and submitted to the UNFCCC her Initial and Second National Communications, the National Adaptation Program of Actions (NAPA), and the Nationally Appropriate Mitigation Actions (NAMA). These documents have been developed to be in line with the national policies and programmes including VISION 2020, the PAGE and relevant sectoral strategies and policies discussed in sections 1.2.2 and 1.2.3 of this report. Vulnerability and adaptation assessments have been conducted during the development of the two National Communications and the NAPA strategic documents and the identified impacts and adaptation options are discussed in sections 1.4.2 and 1.4.3 of this report.

In summary, the climate change strategic reports suggest that under the projected climate change, The Gambia will be warmer (current mean annual temperature increases 0.3°C in 2010 to about 3.9°C in 2100), and drier (mean annual rainfall decreases from about 1% in 2010 to about 54% in 2100; potential evapotranspiration increases by about 10%) (GOTG-NCC, 2013). Ground water recharge is projected to decrease by 3% and the saline front of the River Gambia is projected to reach 250 km upstream from the mouth. These translate to water stress, reduction in arable land, decrease in crop production by about 21 to 44% and a decrease in fish biomass productivity of about 4% by 2100. Projected sea level rise will inundate about 92 km² of the coastal zone, including the mangrove systems on St. Mary's Island and Kombo St. Mary and the strand plains from Barra

to Buniadu Point. The suitability of the habitats for some faunal species is projected to be highly reduced; biomass production in Forests will be lower under the warmer temperatures; some of the grasses in the rangelands will not survive the climate after 40 years; nitrogen uptake by grasses will be reduced, the vegetation will not be palatable and so milk production in livestock will reduce. Overall, food security is threatened and ecosystem productivity and services in The Gambia will be poor under climate change.

Based on the vulnerability assessments and impacts identified in the preceding paragraphs, climate change adaptation options have been determined to support The Gambia in addressing the severe climate change impacts. These options include (a) strengthening early warning systems; (b) crop switching, soil management, irrigation, diversification and intensification of agricultural production, processing, and marketing; (c) promotion of post-harvest technologies; (d) improved livestock and rangeland management; (e) increasing fish production through aquaculture and conservation of post-harvest fishery products; and (f) construction of shoreline stabilization structures and development and implementation of the Integrated Coastal Zone Management Plan.

1.5 Sector selection

1.5.1. Process of Sector Selection

At the TNA Project Inception workshop at the Paradise Hotel on 1st September 2015, participants broke into Working Groups to select priority sectors for Adaptation to climate change. Stakeholders agreed to include Agriculture, Coastal Resources and Water Resources as priority sectors for TNA adaptation in The Gambia. The decisions were based on analysis of some of the national climate change strategic documents, especially the First and Second National Communications, and the NAPA. It was agreed that these three well-defined sectors are selected due to their relevant importance to the national economy, livelihoods of the population and the significantly adverse impacts of climate change on the sectors as identified in section 1.4.2. Out of this bigger group Sectoral Teams were formed to work closely with and support the National Consultant for conducting the rest of work on the development of the TNA.

1.5.2. An Overview of current climate and expected climate change

The climate of The Gambia is characterized by a long dry season (November to May the following year) and a short wet season (June to October). Average temperatures of The Gambia range from 18° to 30°C during the dry season and 23° to 33°C during the wet season. Mean annual temperature has noticeably increased since the 1940s. The lowest mean temperature of 25.8°C was recorded in 1947 whilst the highest mean temperature of 28.2°C was recorded in the year 2000. Average relative humidity (RH) is about 68% in coastal areas and 41% in the hinterland during the dry season, and generally above 77% throughout the country during the wet season. However, RH has also been decreasing since the 1940s, with annual average of over 75% in 1945 dropping to a little over 55% in 2002.

For development of climate change projections of The Gambia, outputs from the Canadian Climate Centre Model (CCC199), the Australian Climate Model (BMRC98) and the Geophysical Fluid Dynamic Laboratory Model (GFDL90) were combined with current climate parameters averaged over the period 1951 to 2000. From projections, an increase in temperature in The Gambia is projected to range from about 0.3°C in 2010 to about 3.9°C in 2100 (Figure 1 below).

Figure 1: Projected of Mean Annual Temperature by Three General Circulation Models (GOTG/SNC, 2013)

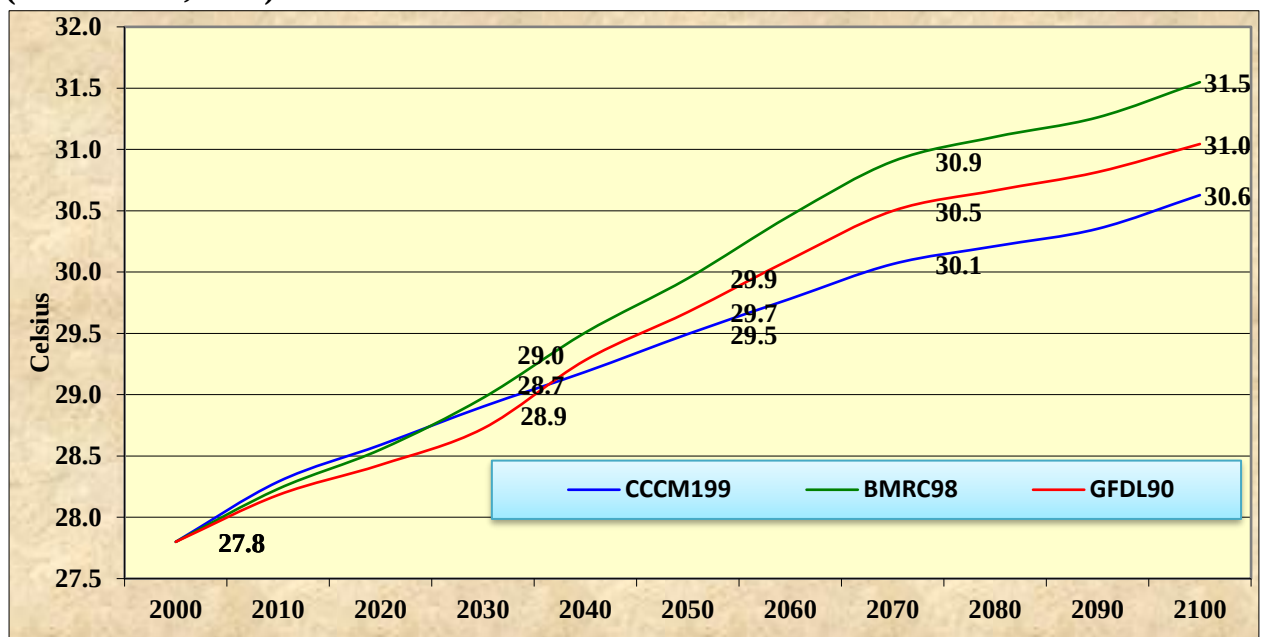
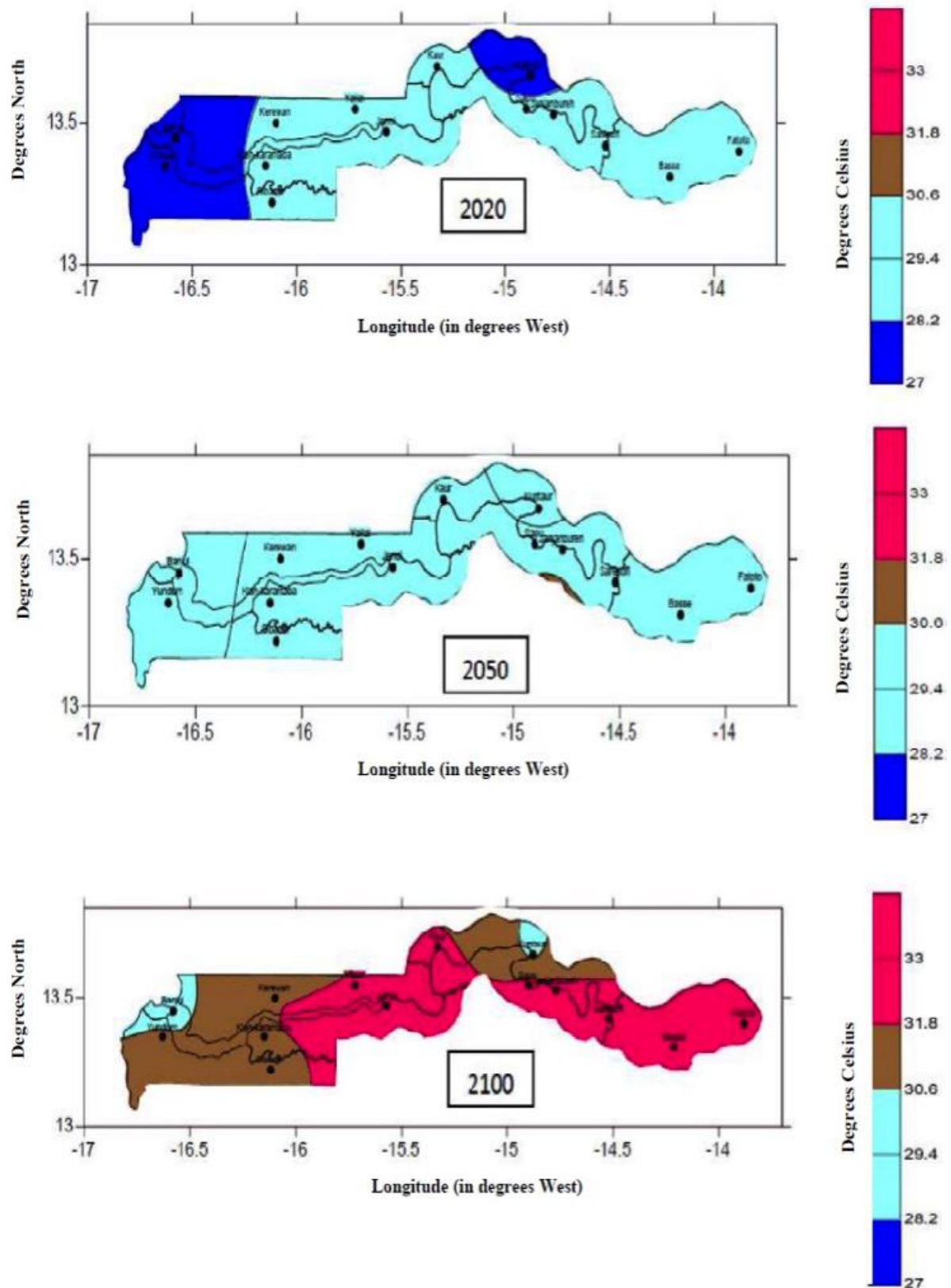


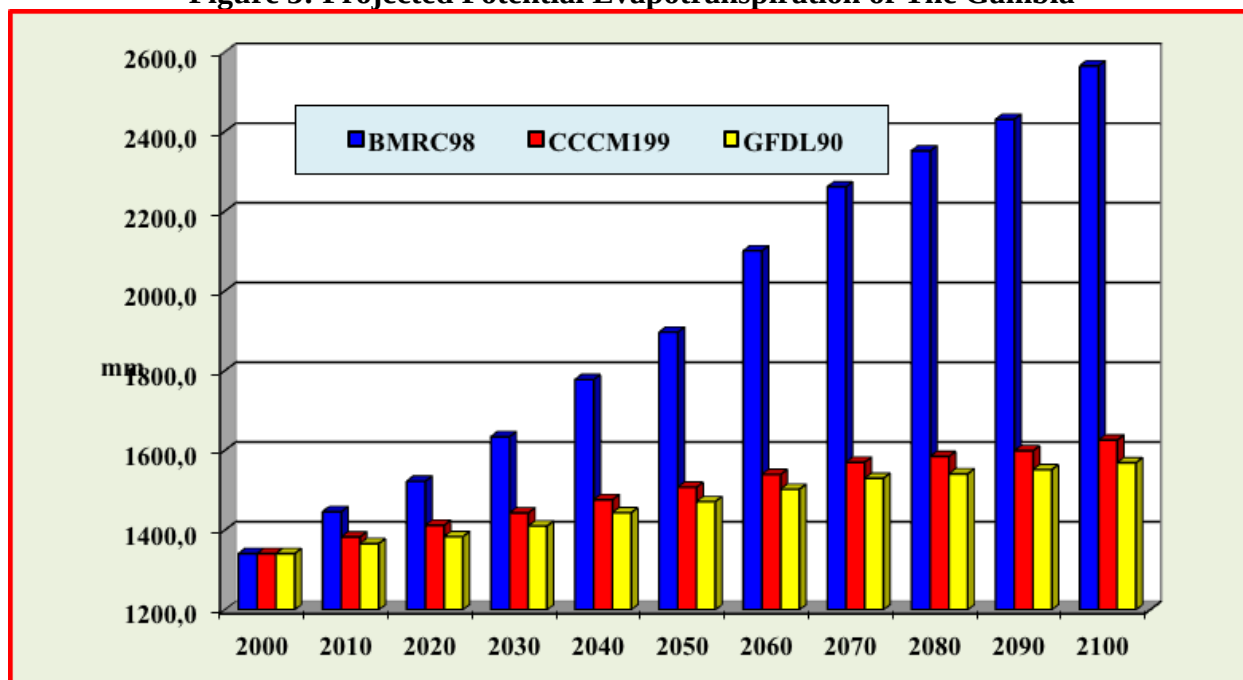
Figure 2 below shows maps of projected mean annual temperatures of The Gambia for the period up to 2100. From these maps it is clear that The Gambia will be more than 3°C warmer than the current climate. By 2020, temperature ranges in the coastal areas and some central parts of the country are from 27 to 28°C while the rest of the country will experience temperatures of 28 to 30°C. By 2050, the whole country will experience temperatures of 27 to 28°C. By 2100 temperatures continue to increase with the coastal areas and the some central parts experiencing temperatures of 28 to 32°C while the rest of the country will experience temperatures of 32 to 34°C.

Figure 2: Maps of Projected Mean Annual Temperature (°C) of The Gambia to 2100 (courtesy of Climate Unit of the Department of Water Resources in 2014)



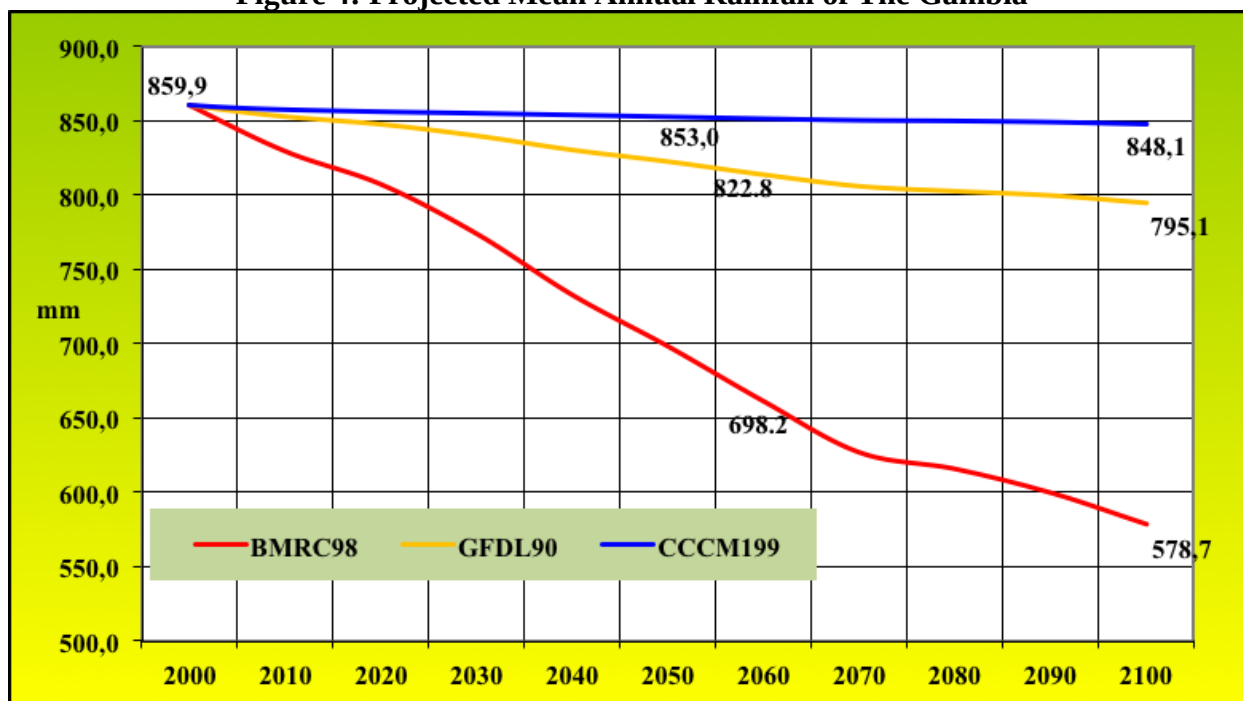
As shown in Figure 3 below, Potential Evapotranspiration (PET) is projected to increase by 17% (1471mm) under the cooler GFDL90 scenario to 91% (2565mm) under the warmest BMRC98 scenario from 1343mm in 2000.

Figure 3: Projected Potential Evapotranspiration of The Gambia



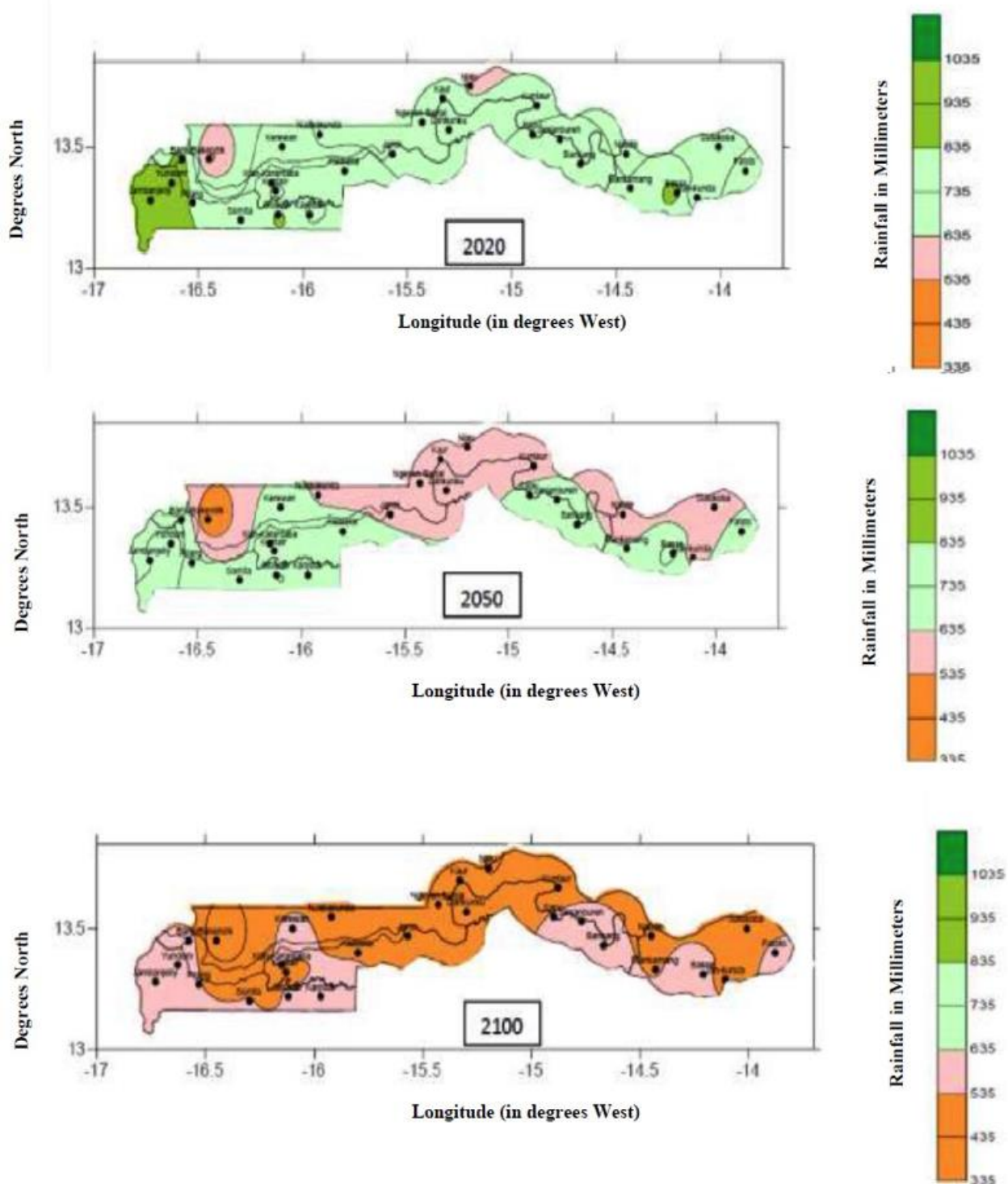
Rainfall in The Gambia is projected to decrease from about 1% in 2010 to about 54% in 2100 (Figure 4 below) with the largest decrease being registered under the warmest climate change scenario (BMRC98).

Figure 4: Projected Mean Annual Rainfall of The Gambia



The maps (Figure 5) below show the projected temporal variation of the annual rainfall in The Gambia from 2020 to 2100. These maps show the gradual drying of The Gambia during this century with the country average rainfall varying between 535 to 935 mm by 2020 while the whole country will receive rainfall of less than 635 mm by 2100

Figure 5: Maps of Projected Annual Rainfall (mm) of The Gambia to 2100 (*courtesy of the Climate Unit of the Department of Water Resources, 2014*)



CHAPTER 2: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

2.4 National Institutions involved in Climate Change

There are mainly five national institutions active on climate change related issues in the Gambia. These are:

1. **The Ministry of Environment, Climate Change, Fisheries, Water and Wildlife (MoECCFWW)** is responsible for policy issues related to climate change. The Minister provides regular Cabinet Papers and briefings to Cabinet. The Ministry also works closely with the National Disaster Management Agency and the Minister serves as the Chairperson of the Disaster Management Forum.
2. **The Department of Water Resources (DWR)** under the Ministry of Environment, Climate Change, Water and Wildlife plays a lead role in the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and also in the monitoring and prediction of weather and climate change for The Gambia. The Director is the Focal point to the UNFCCC and also chairs the National Climate Committee established in 1992. It is the technical body tasked with the technical implementation of the Climate Change Convention in the Gambia.
3. **The National Environment Agency (NEA)** is mandated to coordinate all activities that relate to environmental issues, under the oversight of the National Environmental Management Council. The Agency is also responsible for the implementation of the Gambia Environment Action Plan (GEAP) and the Executive Director serves as the national focal point for the Global Environmental Facility (GEF) as well as for other international environmental conventions.
4. **The Agriculture and Natural Resources (ANR) Working Group** is the policy level body that coordinates the implementations of all Multilateral Environment Agreements, including Climate Change, and major projects and programmes in the Agriculture and Natural Resource sectors. It is co-chaired by the Permanent Secretaries of Ministry of Agriculture, Ministry of Environment, Climate Change, Water and Wildlife and the Ministry of Fisheries. Focal points of all the Multilateral Environmental Agreements (MEAs) and coordinators of major projects and programmes report to the ANR working group.
5. **The National Climate Committee (NCC)**, chaired by the UNFCCC Focal Point, is a Technical Working Group that has the mandate to implement the Climate Change Convention and its Kyoto Protocol in The Gambia. The NCC is a multidisciplinary and multi-sectoral technical body composed of over 40 members from various institutions in the public and private sector, civil society, and other non-state actors. The NCC is responsible for the technical implementation and coordination of climate change assessments and studies on greenhouse gas inventories, greenhouse mitigation assessments, climate change vulnerability, impacts and adaptation assessment and also oversight of climate change projects and programmes in the country.

Task Teams are constituted from the National Climate Committee to undertake tasks identified by the NCC. Such Task Teams include the National GHG Inventory Team; the GHG Mitigation Team; the Vulnerability and Adaptation Team; and the Cross-cutting Team that includes the TNA

Team. Some coordination challenges have been experienced in the past but measures have been taken to address these through a well define National Climate Policy.

2.5 The TNA Project bodies

The appropriate institutional arrangement for the implementation of the TNA Project in The Gambia was finalized at the Inception Workshop conducted at the Paradise Suits Hotel in Kololi on 1st September 2015. The main bodies are the Project Steering Committee, the National TNA Team and the Sectoral Working Groups. The two National Consultants for Mitigation and Adaptation are members of the TNA Team and the Sectoral Working Groups.

2.2.6. Project Steering Committee

The Project Steering Committee (Table 1) of the TNA project in The Gambia is composed of representatives from the Ministry of Environment, Climate Change, Fisheries, Water and Wildlife (MoECCFWW); the Gambia Technical Training Institute (GTTI); Ministry of Energy (MoE), Ministry of Finance & Economic Affairs (MoFEA); Women’s Bureau; NGO Affairs Department; the Association of NGOs (TANGO); Department Of Community Development (DCD); National Environment Agency (NEA); the Gambia Chamber of Commerce and Industry (GCCCI); and Department of Water Resources (DWR, the UNFCCC Focal Point). The Committee is responsible for coordinating policy inputs from relevant ministries as well as key stakeholders from the private sector. The National Project Steering Committee also provides political acceptance of the TNA process and is responsible for guiding the National TNA team.

Table 1: Membership of the TNA Project Steering Committee

#	Name	Institution
1	Mrs. Jahou S. Faal	Gambia Technical Training Institute (GTTI)
2	Lamin Jawara	Ministry of Environment, Climate Change, Fisheries, Water and Wildlife (MoECCFWW)
3	Ndey Fatou Jobe-Sanyang	Women’s Bureau
4	Musu kebba Sonko	NGO Affairs Department
5	Ebrima Sawaneh	Department Of Community Development.
6	Omar Ceesay	National Environment Agency
7	Thomas Roberts	Gambia Chamber of Commerce and Industry (GCCCI)
8	Kemo K. Ceesay	Ministry of Energy
9	Fatou Jagne	Ministry of Finance & Economic Affairs
10	Alpha Jallow, UNFCC FP.	Department of Water Resources
11	Lamin Jatta, NPC	Gambia Technical Training Institute (GTTI)
12	Lamin Mai Touray, NPD	Department of Water Resources

2.2.7. National TNA Team

The National TNA Team is the main decision making body for the project and is composed of a small core group (i.e., the National TNA Committee), and a broader group of stakeholders (i.e., sectoral/technology workgroups) and experts (national consultants), that would aid the core group. The composition of the National TNA team is on the other hand relatively flexible as it may need to induct members from the relevant stakeholder group for specific tasks. For example, if electricity is one of the prioritised sectors for mitigation then a working group would be constituted comprising of stakeholders from utilities, industrial consumers, civil society, regulators, etc.



Figure **: national TNA Team??

The role of the National TNA Committee is to provide leadership to the project in association with the TNA coordinator. Specific responsibilities include:

1. Identifying national development priorities, and priority sectors for technology needs.
2. Deciding on the constitution of sectoral/technological workgroups
3. Approving the technologies and strategies for mitigation and adaptation recommended by sectoral workgroups.
4. Approving the Sectoral Technology Action Plan (a roadmap of policies that will be required for removing barriers and creating the enabling environment) and developing a cross-cutting National Technology Action Plan (TAP) for mitigation and adaptation.

2.2.8. TNA Coordinator

A TNA Project Coordinator was appointed from the National Implementing Entity by the Project Director at the Department of Water Resources under the MoECCFWW, the entity that signed the TNA MoU (Memorandum of Understanding) or Agreement. The TNA Coordinator coordinates the activities of the different groups to ensure that they work together as a team. The TNA Coordinator is the focal point for the TNA project and manager of the overall TNA process. Further,

the coordinator facilitates networking of consultants and technical experts from various sectors, arranges Project Steering Committee and technical meetings and work sessions and reporting of progress to the PSC and the UDP.

2.2.9. National Consultants/Experts

The Consultants are national mitigation and adaptation experts, selected by the National TNA Committee in consultation with UDP. They work in close collaboration with the National TNA Project Steering Committee, the National TNA Team and various working groups, and are directly responsible to the TNA Coordinator. The National Adaptation Consultant has been supporting the entire TNA process by leading and undertaking activities such as review of national and sectoral strategies and plans, identification of adaptation activities and technologies in relevant documents, working with stakeholders to identify and shortlist adaptation technologies, preparing Fact Sheets on the identified technologies, prioritising shortlisted technologies using multi-criteria analysis, and writing of the TNA report.

The national Mitigation and Adaptation Consultants represent an important component of the global TNA project and participate in regional-level capacity building workshops organised by UDP and Regional Centres (RCs). They are responsible for providing process-related and facilitation needed for conducting TNAs and developing Technology Action Plans (TAPs) at the country level. The national consultants assist the TNA coordinator in applying the participatory approach to the TNA process by facilitating the tasks of communication within the national TNA team, outreach to stakeholders, formation of networks, and coordination and communication of work products. In particular, national consultants have the following responsibilities:

1. Provide support in the identification and categorisation of the country's priority sectors, and identification and prioritisation of technologies for mitigation and adaptation through a participatory process with a broad involvement of relevant stakeholders;
2. Facilitate the process with the work groups of analysing how the prioritised technologies can be implemented in the country and how implementation circumstances could be improved by addressing the barriers and developing an enabling framework. The results will be included in follow up barrier analysis and enabling framework (BA&EF) report;
3. Prepare the National TAP, which outlines essential elements of an enabling framework for technology transfer and will consist of market development measures, institutional, regulatory and financial measures, and human and institutional capacity requirements. The TAP also includes a detailed plan of action for implementing the proposed policy measures and assessing the need for external assistance to cover additional implementation costs.
4. Prepare the TNA, BA&EF, TAP and final report for the country. The TAP report will include project ideas.

2.2.10. Sectoral Adaptation Technologies Workgroups

The National TNA Committee constituted two thematic (mitigation and adaptation) working groups to engage relevant stakeholders in the TNA process. The Adaptation Technologies Working Group was further divided into Agriculture, Coastal and Water Resources sectoral working groups which worked with the National Adaptation Consultant to decide on the adaptation technologies appropriate for the given sector, as well as conduct the multi-criteria analysis (MCA) for the prioritization. The Adaptation Sectoral Working Group includes persons drawn from public and private sector departments (Table 2).

Table 2: List of Members of the Adaptation Technologies Working Group

Name	Organization
Lamin Jatta	Gambia Technical Training Institute, Kanifing Industrial Estate.
Momodou Dumbuya	Ministry of Works, Transport & Infrastructure
Amulai Jarjusey	Ministry of Works, Transport & Infrastructure
Muhammed Jabang	National Environment Agency
Mr Alawale	ITC- Kerr Seringe
Yaya Baldeh	Department of Livestock Services
Lallah Badgie	Ministry of Tourism
Mass Njie	Department of Agriculture
Fatou Sillah	Kanifing Municipal Council
Ebou Mass Mbaye	Department of Fisheries
Saloum Jatta	Department of Fisheries
Alpha Jallow	Department of Water Resources
Bai Lamin Sillah	Department of Water Resources
Landing Bojang	Department of Water Resources
Yusupha Bojang	Department of Water Resources
Alasana Bojang	Department of Water Resources
Saikou Sanyang	Department of Water Resources
Binta Manneh	Department of Water Resources
Dr. Momodou Njie	Blue Gold Consultancy Services
Lamin Mai Touray	Department of Water Resources

2.6 Stakeholder Engagement Process followed in the TNA

The Memorandum of Understanding (MOU) or Agreement between the Government of The Gambia and the UDP on collaboration to conduct the Gambia Technology Needs Assessment was signed in 2015. The TNA Project Coordinator was appointed on 1 July 2015 and the Project Steering Committee was constituted on 21 July 2015.

A UDP Scoping Mission to The Gambia led by Drs. Todd Ngara and Bothwell Batidzirai, was conducted from 30 March to 2 April 2015. The objectives of the Mission included information sharing, stakeholder identification, and plan for the implementation of the TNA Project in The Gambia. The Mission met many stakeholders both at the individual and institutional level. The National Mitigation and Adaptation experts to serve as consultants were also identified.

The First Regional Capacity Building Workshop for the TNA Phase II for Anglophone group of countries in Africa was held from 22 to 24 June 2015 in Arusha, Tanzania. The workshop was attended by the TNA Coordinators and National Consultants from the seven Anglophone African

countries participating in the TNA Phase II, comprising Seychelles, Egypt, Jordan, Gambia, Swaziland, Mozambique and Tanzania. The objectives of the workshop were to (a) provide the National Consultants and experts with training in the selection of technologies and strategies for climate change mitigation and adaptation, in conducting stakeholder consultation processes, the process of selecting technologies and reporting the outcomes in the ‘Technology Needs Assessment (TNA)’ Report and database support, and (b) serve as a forum to introduce countries to the Regional Centre, the Energy Research Centre (ERC), which also provides facilitation in terms of specific technology needs.

On 1st September 2015, stakeholders participated in the TNA Project’s Inception Workshop held at the Paradise Suits Hotel in Bijilo, Kombo North, and West Coast Region (WCR). The workshop was attended by participants drawn from key organizations from public and private sectors, civil society organizations and the two National Consultants. The Inception Workshop facilitated enhanced awareness and active engagement of a broader group of stakeholders on the TNA process, finalization of the institutional set-up for the implementation of the TNA Project, selection of economic sectors for assessment of mitigation and adaptation technologies, and facilitated agreement on the implementation plan of the project.

Among the institutions agreed at the Inception Workshop were the Sectoral Working Groups that would work with the National Consultant to conduct the rest of the project activities. For the Adaptation Technologies Assessment, there were three (Agriculture, Coastal and Water Resources) Working Groups. The first workshop that brought all the Mitigation and Adaptation Working Groups together was held on 21st November 2015 with the objective of outlining the requirements of the collaborative work of the Working Groups and the National Consultants, including the confirmation of the long list of sectoral technologies to be assessed, and review of the long list to a shorter and more manageable list of technologies for prioritization. Members of the Working Groups were also introduced to and trained on the MCA with particular examples on prioritization of technologies identified for the Energy Sector.

During the months of November and December 2015, the National Consultants also developed and shared with members of the Working Groups a number of Factsheets for every technology identified at the Inception Workshop as well as other technologies identified by the National Consultants through literature review of national policies, plans, strategies and projects.

The second workshop to engage the Work Groups was held on 16th January 2016 and this was mainly the Adaptation Working Group. Participants at this Workshop worked with the National Consultant to use the MCA software to prioritize adaptation technologies for the Coastal Resources sector. By the end of this workshop some members of the Sectoral Working Groups were well grounded in the execution of the MCA. The National Consultants then shared the Factsheets and executed the MCA for prioritization of mitigation (transport and waste) and adaptation (agriculture and water resources) technologies. Chapter 3 provides details on the collaboration between the Members of the Working Groups, the National Consultants and the Project Coordinator.



Figure **: Training Session on MCA of Mitigation Technologies



Figure **: Training Session on MCA of Adaptation Technologies for Water Resources

The stakeholder engagement is expected to continue beyond the production of the Report of the Technology Needs Assessment of The Gambia. Stakeholders will be continuously engaged in the production of the rest of deliverables of the TNA Project including a report on the Barrier Analysis and the Technology Action Plan (TAP).

CHAPTER 3: TECHNOLOGY PRIORITISATION FOR THE AGRICULTURE SECTOR

3.1 Key Climate Change Vulnerabilities in Agriculture Sector

The projected changes in climate discussed in sub-section 1.4.2 above will have significant adverse impacts on the agriculture sector of The Gambia. A summary of the impacts on agriculture and livestock based on assessments in the Initial National Communication (GOTG/NCC, 2003), the NAPA (GoTG/NCC, 2007) and the Second National Communications (GoTG/NCC, 2013) is presented under this sector. During the development of the Initial National Communications of The Gambia, Global Circulation Model (GCM) outputs from the Canadian Climate Center Model (CCCM) (Boer et al., 1992), the Hadley Centre General Circulation Models with greenhouse gases alone (HCGG, Hagler Bailly Services, Inc, 1997), and with sulphate aerosols (HCGS, Hagler Bailly Services, Inc, 1997) models were combined with current climate (CURR) data and Biophysical Models to conduct simulations of the impacts of climate change on major sectors of The Gambia. For the development of the Second National Communications of The Gambia to the UNFCCC (GoTG-NCC, 2013), the Canadian Climate Centre Model (CCC199), the Australian GCM (BMRC98) and the Global Fluid Dynamic Laboratory GCM (GFDL90) were the three Global Climate Models used to conduct simulations of the impacts of climate change on the national economy.

By 2100, total dry matter production of the maize crop would decrease (Figure 6) by 19 to 35%, grain weight would decrease by 28% to 40%, leaf and stem weights would decrease by 18 to 35% and 17 to 34%, respectively. Significant increases in the quantity of nitrogen leached as well as the decrease in soil nitrogen, as climate changes, will cause the nutritional value of the biomass products from maize to also decrease due to the decrease in nitrogen content.

Results of the growth parameters of the early millet crop (Figure 7 below), suggest that total dry matter (leaf, stem and grain) produced decreases by 1% to 21% by 2100. Of these parameters, grain weight is estimated to be most affected with deviations from current climate conditions, ranging from 3 - 30%. Simulation results also show that nitrogen leached from the root zone is estimated to be 25% higher in climate change scenarios than under current climate. Hence nitrogen uptake and total nitrogen content of the plants are reduced below current climate estimates by 7 - 32% and 14 - 33% respectively.

For Late Millet and as shown in Figure 8 and by 2100, the simulations show that total dry matter (leaf, stem, root and grain) produced is estimated to decrease by 25 to 44% under all the model scenarios, but grain weight is particularly affected as it is estimated to decrease by 29% to 46% below current climate estimates.

Simulation of growth of the groundnut crop suggests that all growth parameters are estimated to be significantly higher under climate change scenarios by 2100, with grain weight estimated to increase by 9% to 25% above the current climate's production. From Figure 9, total dry matter production increases by 15 to 47% by 2100. With regard to nitrogen utilization, the simulation results suggest that nitrogen uptake is estimated to increase by 3% to 25% under climate change scenarios than under the current climate conditions. Although the quantity of nitrogen fixed is

estimated to increase significantly under climate change scenarios, soil nitrogen is estimated to decrease slightly under projected climate change conditions than under current conditions. This could be attributed to the fact that the amount of nitrogen leached under climate change conditions as compared to the baseline is quite significant.

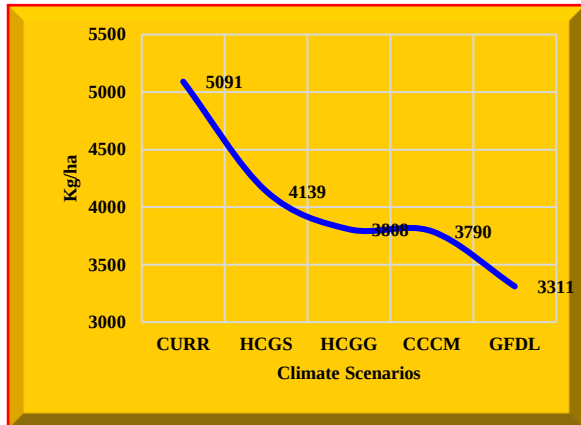


Figure 6: Simulated Dry Matter (Kg/ha) Production in Maize under Current (CURR) Climate and Climate Change Scenarios

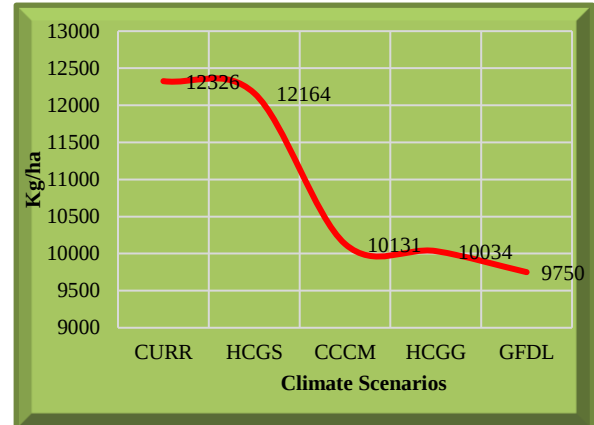


Figure 7: Simulated Dry Matter (Kg/ha) Production in Early Millet under Current (CURR) Climate and Climate Change Scenarios



Figure 8: Simulated Dry Matter (Kg/ha) Production for Late Millet under Current (CURR) Climate and Climate Change Scenarios

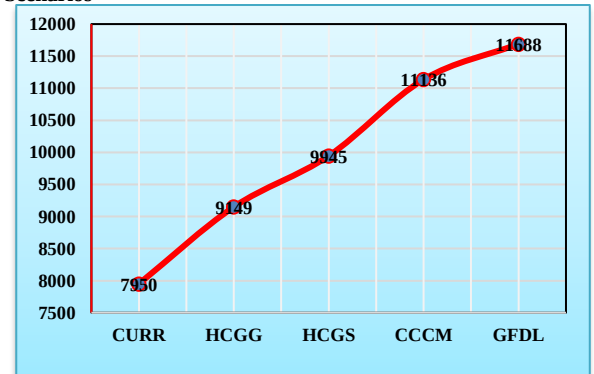
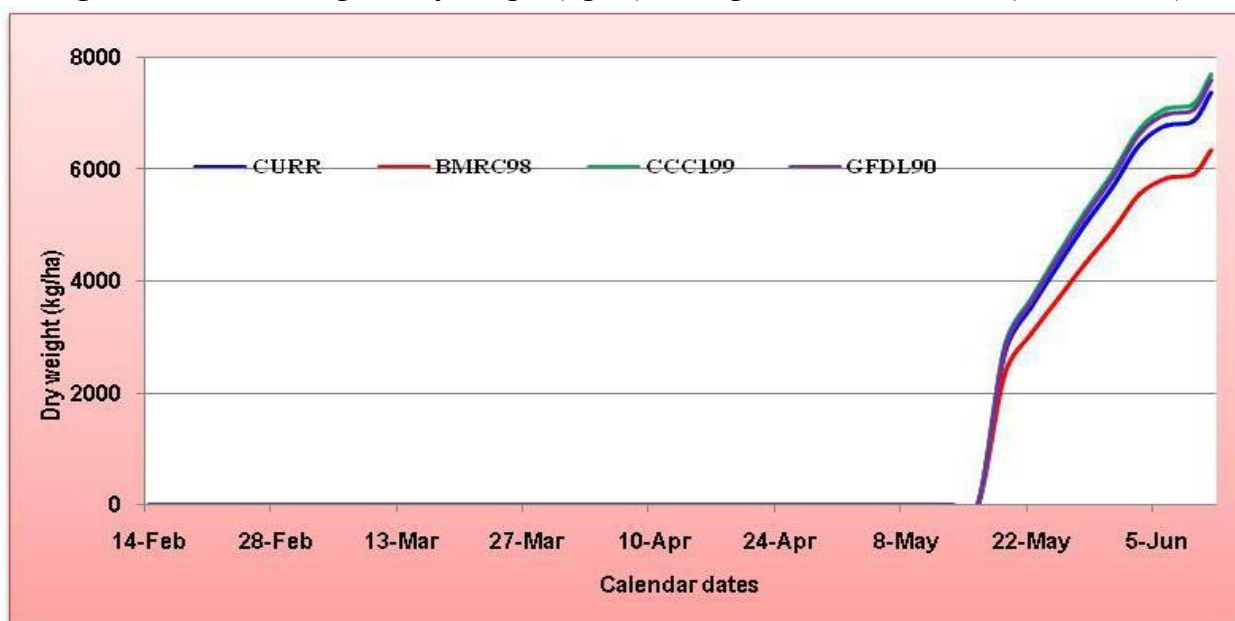


Figure 9: Simulated Dry Matter Production for Groundnuts under Baseline and Climate Change Production

The impact of climate change on irrigated rice production was assessed with a crop growth model using BMRC98, CCC199 and GDFL90 climate scenarios as driving inputs. Figure 10 below illustrates that yield increases are expected in the order of 0.2 to 0.3 tons/ha under the CCC199 and GDFL90 climate change scenarios. Additionally, it shows a drop in yield from 7.4 tons/ha under the reference scenario to 6.3 tons/ha under the BMRC98 scenario; a drop of approximately 16%.

Figure 10: Simulated grain dry weight (kg/ha) of irrigated rice at Kuntaur (The Gambia).



3.2 Decision context

The following discussions represent ongoing and planned climate change adaptation projects to reduce vulnerabilities and meet adaptation needs in the Agriculture sector of The Gambia. Relevant policies and strategies have been discussed under section 1.2.

1. **GoTG/GCF/UNEP Large-scale ecosystem-based adaptation in the Gambia: developing a climate resilient, natural resource-based economy.** Climate change has brought the urgent need for a transformational change in rural Gambia that will increase crop and livestock productivity, and increase the supply of resources from forest ecosystems under climate change conditions. The proposed GCF project will use large-scale Ecosystem-based Adaptation (EbA) – a cost-effective and low-risk approach for building climate resilience over large areas – to effect this transformational change. The main objective of the GCF project is to implement large-scale Ecosystem-based Adaptation (EbA) within and adjacent to agricultural areas, community-managed forest reserves and wildlife conservation areas of The Gambia, thereby building the climate-resilience of rural Gambian communities and facilitating the development of a sustainable natural resource-based (green) economy. This objective will be achieved through large-scale EbA to build a climate-resilient natural resource base across The Gambia leading to the provision of adaptation and commercial benefits for local communities, government and the private sector in The Gambia through EbA interventions in agricultural landscapes and degraded ecosystems.
2. **GOTG/GEF/UNDP/UNEP LDCF Climate change early warning system:** The Government of The Gambia (GOTG) has accessed funding from the Least Developed Countries Fund (LDCF) under the Climate Change Convention to strengthen climate

information and early warning systems for climate resilient development and adaptation to climate change. The project is being implemented to increase national and sectoral adaptive capacities to respond to the impacts of climate change, including variability; and promote transfer and adoption of adaptation technologies. The Meteorological and Hydrological Services of the Department of Water Resources are the major beneficiaries. Other beneficiaries include the media, local communities, farmers, fisher-folk and public and private sector entities. Climate change has already been integrated in the Agriculture and Natural Resources Policy and from 2016 the project will work with 14 Pilot Sites to develop climate change integrated local development plans that include agriculture.

3. Under Phase I (2016 to 2017) of the 11th EDF NIP – 2015-2020, the **Agriculture for economic growth and food security/nutrition** project is proposed. The overall objective of the project is to contribute to sustainable growth in the agriculture sector and reduce food insecurity and malnutrition. The project has three specific objectives. The first specific objective is to increase agricultural productivity/diversification and access to food. Expected results include (a) strengthened extension services and farmer capacities, (b) increased sustainable production/productivity/diversification and enhanced quality of selected crops and livestock, and (c) increased access to quality food via social safety nets for improved nut status. The second specific objective is to increase the participation of the most vulnerable small-holder farmers in value chains. Expected results are (a) improved functioning of national cooperative and association bodies in agriculture sector and (b) better market access for small-holder farmers (development of value chain opportunities, access to rural finance, etc.). The third specific objective is to enhance information systems, crises management and prevention. The expected results are (a) improved information gathering and dissemination on food security and nutrition (early warning services, statistics, market information system), and improved implementation of risk mitigation measures (disaster risk reduction (DRR –climate change adaptation) CCA and resilience, disaster risk management DRM, insurance tools, nutrition and social safety nets).
4. **GoTG/GEF/FAO Project entitled “Adapting Agriculture to Climate Change in The Gambia”** has the objective to promote sustainable and diversified livelihood strategies for reducing the impacts of climate variability and change in agriculture and livestock sector. The project has the following four components:
 - **Component 1** is on strengthening institutional and technical capacity for adaptation to climate change in agriculture sector and must deliver (a) strengthened adaptive capacity of 4 target institutions at the national level and 4 regional centres to reduce risks of climate variability and change in the agriculture sector covering 130 villages; (b) mainstreamed climate change adaptation priorities into 4 major national agriculture and livestock policies, plans and programmes; and (c) strengthened institutional and technical capacity of two technical services and a quality control laboratory to promote value added products and to support crop diversification and improved linkages with financial institutions and markets;
 - **Component 2** provides assessment of vulnerabilities, risks and dissemination of timely risk information to users at all levels and will ultimately produce (a) increased

knowledge and understanding of vulnerability and risk assessment tools and agro-climatic monitoring and Early Warning systems for Food Security by 4 national level institutions; and (b) increased understanding of climate information services by the Ministry of Agriculture and tailored climate information is disseminated to targeted vulnerable communities in 4 administrative regions.

- **Component 3** promotes diversification of livelihood strategies and intensification of agriculture production, processing and marketing leading to (a) diversified livelihoods and sources of income improved for vulnerable households and communities in 4 targeted administrative regions; (b) strengthened climate-resilient livelihoods of target population in 4 administrative regions by promoting sustainable crop intensification and innovative, and crop improvement and management practices.
- **Component 4** will improve livestock production and management practices for sustaining livelihoods of local communities and will deliver (a) strengthened adaptive capacity of targeted local institutions and populations in 26 districts by promoting improved poultry, small ruminants and cattle production practices, (b) improved management and increased access to livelihood assets in 4 targeted administrative regions to sustain sources of income by livestock dependent communities.

3.3 Overview of Existing Technologies in Agriculture Sector

Existing agricultural and food security technologies being developed, disseminated and implemented in The Gambia include irrigation (tidal, drip and sprinkler), aquaculture, water harvesting from surface runoff, crop breeding, and livestock breeding.

The National Agricultural Research Institute (NARI) is the principal research organization in The Gambia and its research and demonstration objectives include, among others, achieving greater food security through intensification and diversification of crop, livestock and fish production and to consolidate the natural resource base of agriculture. Figure 11 below shows some of the research programmes under NARI which are technology related and these technologies are demonstrated and applied by farmers. All the programmes and technologies are climate and climate change relevant.

Research at NARI is conducted at three laboratories covering: pest management, soil analysis and food quality control. In collaboration with stakeholders, NARI transfers and disseminates technologies through farmer field schools (Figure 12); group methods (field days, field trips, etc.) and individual method (demonstration). Strategies for technology transfer include institutionalized liaison office between NARI and stakeholders; organization of bimonthly meetings between NARI and stakeholders on the progress of research and response from farmers; and organization of Agro-ecological village (AEV) approach (Figure 13) to present research findings to stakeholders. Some examples of such technologies include:

- Introduction and release of improved varieties of rice, millet, sorghum, groundnuts, fruit trees, cowpeas, root and tubers and other crops;

- A nationwide survey produced and disseminated soil fertility maps identifying sites for optimum crop production and plant nutrient in both the lowland and upland ecologies.



Figure 11: NARI Research Programmes and relevant technologies



Figure 12: National Agricultural Research Institute (NARI) Farmer Field School



Figure 13: The Agro-Ecological Village Approach (Gomez et al, 2013)

Irrigation technologies are applicable in all parts of The Gambia. Tidal irrigation systems are common in the upper reaches of the River Gambia with fresh water throughout the year. Irrigation occurs through the movement of water over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Through the application of this technology, cultivated land on both banks of the river is flooded. The flow is controlled by dikes, usually plugged by soil. Due to the application of this technology, a double cropping of rice is achieved annually in a country with seven months of dry season. Double cropping of 167 ha and 850 ha is achieved annually at Jahally and Pacharr, respectively. This contributes to food security under reduced rainfall as the climate warms. The rice produced is used for consumption and as a cash crop. Farmers are able to sell their products and generate income. Thus, socially the technology is found attractive and helps the farmers to have enough food and cash for other social needs such as health and education.

Drip and Sprinkler irrigations are applied at smaller scales compared to tidal irrigations.

Conservation agriculture (CA) is an agricultural system that aims at soil and water conservation, nutrient improvement and enhanced production. Conservative agriculture technologies are based on the principles of (a) minimal soil disturbance (zero-tillage), (b) maintenance of good soil cover (cover crops, residues and mulches), and (c) appropriate crop rotation or crop association depending on the availability of land. Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible and it aims at making better use of agricultural resources through the integrated management of soil, water and biological inputs. Zero Tillage improves the soil, increases production and decreases the cost of production. It consists of improved agricultural packages including (a) crop residue from previous crop and crop rotation; (b) application of herbicide for control of emerging and non emerging weeds (pre- post emergence herbicides); (c)

planting in rows and application of fertilizer in one operation by a special planter; and (d) starting agricultural operations after the soil has received 110 mm of rainfall.

Zero tillage, as a component of Conservative Agriculture, was applied in The Gambia on a relatively small scale in the 1980s and 1990s. This simple and cost-effective approach to increasing the climate resilience of agriculture is particularly well suited to low input rain-fed agricultural systems such as those in The Gambia. Zero tillage improves the productivity in rain-fed and irrigated farming systems. A fundamental criterion related to coverage is that annual rainfall must exceed 600mm. Thus, the targeted area for transfer and application of the zero tillage system is geographically large for The Gambia as rainfall is everywhere equal to or greater than 600mm.

However, due to increased human and animal population, and the reduction in productivity due to negative impacts of climate variability (which is now compounded by climate change), there is now the need to grow and produce more food in a shorter period. Agricultural mechanization was introduced which has negative impacts on the shallow and poor soils of The Gambia. Productivity continues to decline and there is need to go back to conservative agriculture which is recommended as a climate resilient agricultural technique because conservation of soil organic matter increases the fertility and water holding capacity of soils. The CA approach is compatible with the use of green manures to increase soil fertility. Intercropping, as a component of CA, involves planting two or more crops in close association, often focusing on nitrogen-fixing species. This approach can increase the climate resilience of agriculture by diversifying the risk of monoculture farming, as well as by increasing soil fertility through planting of nitrogen fixing crops.

3.4 Adaptation Technology Options for Agriculture Sector and Their Main Adaptation benefits

Based on desk review of existing climate change strategic documents, agriculture strategic documents and, existing and proposed climate change related programme and project documents, the National Adaptation Consultant identified relevant climate change adaptation activities and the technologies required to implement those adaptation activities. The second column of Table 3 below is a long list of 27 climate change adaptation technologies for potential implementation in the Agriculture sector of The Gambia. Some of the adaptation options have common adaptation technologies.

The National Adaptation Consultant and stakeholders reduced this long list to eight high priority adaptation technologies (Tidal Irrigation; Drip Irrigation; Sprinkler Irrigation; Food Processing, Preservation and storage; Aquaculture; Crop Breeding; Livestock Breeding and Feed Enhancement; and Conservation Agriculture) for the Agriculture sector. Brief characteristics of the selected technologies are found in the fact sheets (Annex I). The National Adaptation Consultant then prepared technology factsheets for each selected technology option for the Agriculture sector. The contents of these factsheets include: brief description of the technology; the costs of the technology; the application potential in the country; technical aspects such as geographical applicability range and maturity; and the potential for reduction of vulnerability as

well as its social, economic, and environmental benefits. The Technology factsheets developed by the National Consultant were circulated to the Agriculture Adaptation Technologies Working Group for review. The Factsheets were used by the stakeholders in selecting the technologies for further analysis. Three adaptation technologies for the Agriculture sector are prioritised based on Multi-Criteria Analysis (MCA).

Table 3: Identified adaptation options and corresponding adaptation technologies for the Agriculture sector

Adaption Options identified	Corresponding Adaptation Technologies
1. Rehabilitation of Early Warning Systems on Climate-Related Natural Hazards	1. Climate Early warning systems
2. Switching to drought and salinity tolerant, and high yielding crop varieties,	2. Crop switch and diversification 3. Crop breeding
3. Improve water-use efficiency of crops through management of soil fertility, improved irrigation systems,	4. Water Use Efficiency 5. Tidal irrigation 6. Drip irrigation 7. Sprinkler irrigation
4. Promote and encourage improved post harvest technologies through demonstration, promotion and diffusion of improved post harvest technologies that will have the long-term effect of reducing extensive cultivation of marginal lands.	8. Post Harvest management
5. Diversification and Intensification of Agricultural Production, Processing, and Marketing	9. Food processing, preservation and storage
6. Improved livestock and rangeland management for food security and environmental sustainability	10. Feed enhancement
7. Increasing fish production through aquaculture and conservation of post harvest fishery products	11. Aquaculture 12. Post Harvest management
8. Promote smart and sustainable agricultural production methods that have great mitigation and adaptation potential, particularly with regard to topsoil organic matter fixation, soil fertility and water-holding capacity, and increasing yields in areas with medium to low-input agriculture and in agroforestry.	13. Efficient Soil Management 14. Conservation Agriculture 15. Agroforestry
9. A strong technology policy with a focus on adaptation and dissemination of green technologies and the treatment of green economic activities such as “infant industries” that require appropriate support such as access to credit and some level of protection.	16. Technology Policy
10. Improvement of Agricultural Land and Water Management;	17. Conservation agriculture
11. Development of Agricultural Value Chains and Market Promotion;	18. Agriculture value chain and markets
12. National Food and Nutrition Security; selection of drought-, pest- disease-, and salinity-resistant, high-yield crop varieties for local conditions;	19. Crop breeding
13. Animal husbandry, rangeland regeneration/restoration to buttress traditional livestock production systems and minimize farmer-herder conflicts including increase in fodder production from intensive feed gardens; promote crop/livestock integration; improve feed conservation techniques and access to supplements; explore opportunities for selective/cross-breeding of Ndama cows with higher milk-producing breeds.	20. Rangeland management 21. Feed Enhancement 22. Animal breeding
14. Regulatory measures that discourage cultivation on marginal areas; cooked food waste reduction; and diversification of eating habit (change from rice to other cereals)	23. Regulations on cultivation 24. Food waste management 25. Change in eating habits
15. Conservative agriculture techniques to conserve and increase the soil organic matter content, fertility and water holding capacity; improve the productivity of agricultural systems; and contribute to food security.	26. Conservation agriculture 27. Soil management

3.5 Criteria and process of technology prioritisation

To prioritize the technologies selected for the agriculture sector, the stakeholder team and the National Adaptation Consultant identified and agreed to the criteria shown in Table 4 below.

Table 4: List of criteria, their categories and the allocated weights used in the prioritization of climate change adaptation technologies for the Agriculture sector

Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)	Allocated Weights in percentage (Social, 50%, Economic 35% and Environmental 15%)
1. Increased productivity	Social	Ordinal	High	25%
2. Biodiversity Conserved	Environmental	Ordinal	High	15%
3. Total Cost	Economic	US\$	Low	10%
4. Return on Investments	Economic	Ordinal	Low	25%
5. Creation of Employment	Social	Ordinal	High	10%
6. Health status	Social	Ordinal	High	5%
7. Applicability by farmers	Social	Ordinal	High	10%

From Table 4 above, two of the criteria are categorized as economic, one as environmental and four are categorized as social. The Table also shows the units chosen and the preference attached to the criteria. Due to absence of comparable units between criteria, ordinal units are used and are based on a scale of 1 – 5, with 5 being the highest preferred and 1 being least preferred, except for cost related criteria where the reverse is the case.

In addressing the need for climate change adaptation technologies in the agriculture sector, stakeholders attached highest preference and allocated the highest weight of 50% to the social category of criteria. The economic and environment categories were allocated weights of 35% and 15% respectively. Economic (cost factors) received low preference and weights because stakeholders are of the opinion that cost should not be an overriding barrier to the acquisition and application of the adaptation technologies and also the technologies should be low cost and sustainable. Stakeholders interpreted the social criterion of increased productivity to mean that the application of the technologies must lead to increased yields, income and capability to easily meet the social needs of the family including education and health. The application of the technologies must also be capable of creating employment and reducing susceptibility to health related issues such as malnutrition, stunting and memory retardation. The eight adaptation technologies are then evaluated based on the seven criteria and weights in Table 4 above.

3.6 Results of technology prioritisation

Applications of the criteria, the units and weights to the adaptation technology options produced the following ranking of the eight options. From Table 5, the highest ranked adaptation technology option is Conservation Agriculture (96) followed by Tidal Irrigation (78) and Aquaculture (73). Factsheets on all the technology options can be found in Annex I and a brief description of the three priority technologies (Conservation Agriculture, Tidal Irrigation and Aquaculture) follows below.

Table 5: Prioritized and Ranked Technologies for the Agriculture Sector

Rank	Option	Weighted Score
1	Conservation Agriculture	96.0
2	Tidal Irrigation	77.6
3	Aquaculture	73.0
4	Food Processing and Preservation	54.2
5	Drip Irrigation	40.0
6	Sprinkler Irrigation	32.5
7	Livestock Breeding and Feed Enhancement	10.1
8	Crop Breeding	9.8

3.6.1 Conservation Agriculture

Conservation agriculture system aims at soil and water conservation, nutrient improvement and enhanced production. Conservative agriculture technologies are based on the principles of (a) minimal soil disturbance (zero-tillage), (b) maintenance of good soil cover (cover crops, residues and mulches), and (c) appropriate crop rotation or crop association depending on the availability of land. Consequently soil organic matter is conserved, water retention is increased, erosion and pollution are reduced, and the productivity of agricultural systems is increased even during the prevalence of drier climate phenomena such as droughts. The Conservation Agriculture (CA) approach is recommended as a climate-resilient agricultural technique because conservation of soil organic matter increases the fertility and water holding capacity of soils. This simple and cost-effective approach to increasing the climate resilience of agriculture is particularly well-suited to low-input rain-fed agricultural systems such as those in The Gambia. Therefore, food security is assured during dry periods especially in arid and semi-arid climatic conditions familiar to The Gambia.

Conservative Agriculture is less expensive in terms of capital cost (for machinery), in labor and energy than conventional agriculture. Cost associated with establishment of one production unit using zero tillage equipment (tractor, 90HP+planter+ sprayer) is 31,600 USD. In field crops, the cost of implementing the technology is reduced to the cost of the seeder or planter (2,000 US\$/yr) (MoE/URC/GEF, 2012). Application of conservative agriculture technologies shows that the cost of production is maintained as the inputs do not augment because soil fertility and water content are preserved. The major saving will be in terms of costs for tillage and land preparation for plantation. Crops grown under conservation agriculture have shown to be more resilient to drought conditions, leading to minimal inter-annual yield variation (MoE/URC/GEF, 2012).

Zero tillage improves the productivity in rain-fed and irrigated farming systems. The targeted area for transfer and application of the zero tillage system is geographically large for The Gambia as rainfall in the whole country is equal to or greater than 600mm. There will be increase in farmers' incomes, increased food production and encouragement of private sector investments and thus new job opportunities in the production of agricultural crops. An overall yield stability, a reduction in cost of production, and increases in farmer's income are realized. Revenue increases of about

760\$/ha/yr for cereal/legumes have been registered (MoE/URC/GEF, 2012). The social benefits of zero tillage include improvement of living standards, upgrading the livelihood skills of farmers and enhancing their resilience to climatic and external economic shocks. Health status of communities will improve. Environmentally, soil is preserved from the adverse impacts of climate (wind, rain, high temperatures) and evaporation is reduced, which increases soil water content and soil organic matter. Preservation of soil due to zero tillage also reduces greenhouse gas emissions. Water retention and slowed surface runoff increases chances of the maintenance of soil cover, enhances biodiversity in the soil, reduces desertification and increases resilience to floods (Gomez et al., 2013).

Opportunities include the potential reversal of declining crop productivity through investment in zero tillage in rain fed areas; and the minimization of weeds and improvement of soil structure over long periods, leading to a decrease in the cost of production. Heavy machinery and intensive applications of artificial fertilizers are not suitable for the soil conditions of The Gambia. Hence, conservation agriculture is acceptable to farmers and agriculturalists alike. Products of conservation agriculture are more environmental friendly and carry lesser pesticide residues. These products, therefore have higher competitive potential on the market.

Barriers include the high application cost of zero tillage; also conservation agriculture is not recommended in soils with high clay content, in humid areas with shallow water table, in saline soils and for crops with no residues left and that small holders are unable to apply economically viable crop rotations, and unable to access to machinery.

3.6.2 Tidal Irrigation:

In tidal irrigation systems, water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. This is common in the upper reaches of the River Gambia which is fresh throughout the year.

Initial, operations and maintenance costs are relatively low. Annual cost may be estimated at \$40/ha and operation and maintenance costs are \$220/ha/yr. With a resultant yield per hectare of 9 tons/yr, this translates to an annual cost of \$70/ton. This technology is good because once the intake structures and irrigation channels are constructed the operation is relatively cost free.³

The rice produced is used for consumption and as a cash crop. Stakeholders are able to sell their products and generate income. Thus, socially the technology is found viable and helps the farmers to have enough food and cash for other social benefits such as for health and education purposes. There are potentials for the business and private sector entities to be involved in the manufacture and/or importation of spare parts for the construction and maintenance of the irrigation infrastructure.

³ www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8a/gambia.asp

Applications of the technologies are accompanied by some disadvantages. Tidal irrigation is only applicable in the eastern half of the length of the River Gambia. The breeding of mosquitoes and snails is enhanced by water ponding on the farms, which could lead to public health concerns if control measures are not taken.

3.6.3 Aquaculture and Fish Farming

Aquaculture is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants and involves cultivating freshwater and saltwater populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish. Mariculture refers to aquaculture practiced in marine environments. Particular kinds of aquaculture include fish farming, shrimp farming, oyster farming, algaculture (such as seaweed farming), and the cultivation of ornamental fish. The farming of fish is the most common form of aquaculture. It involves raising fish commercially in tanks, ponds or ocean enclosures, usually for food. Fish species raised by fish farms include salmon, tilapia and catfish.

Economically, aquaculture products fill a distinctive niche in the market, that of the high value, high quality seafood product (e.g. smoked salmon, fresh oysters). These products will complement, rather than compete with, the supply from wild fisheries in the marketplace. In the short-to medium-term, it should be recognized though that the main factors which will determine the development of aquaculture is the ability to develop markets, although environmental restrictions and disease may constrain developments for some species.

A decrease in fish stocks is projected under climate change and the relative contribution of aquaculture is likely to increase due to the decline of wild stocks and the imposition of tighter fishing regulations. The social and economic impacts of aquaculture include increase in fish supplies, reduction in fish price, export earnings, creation of employment and improved infrastructure in rural areas. Aquaculture can be a focus for rural development and stabilization, and a source of employment opportunities in depressed rural economies. Aquaculture can generate significant social and economic benefits at a regional level. The creation of employment opportunities in less fortunate rural areas is often cited as one of the most important reasons why local and national governments have been willing to encourage the development of aquaculture. The three most obvious benefits have been a noticeable decrease in the price of some species, an increase in consumer surplus for this produce and the creation of new products.

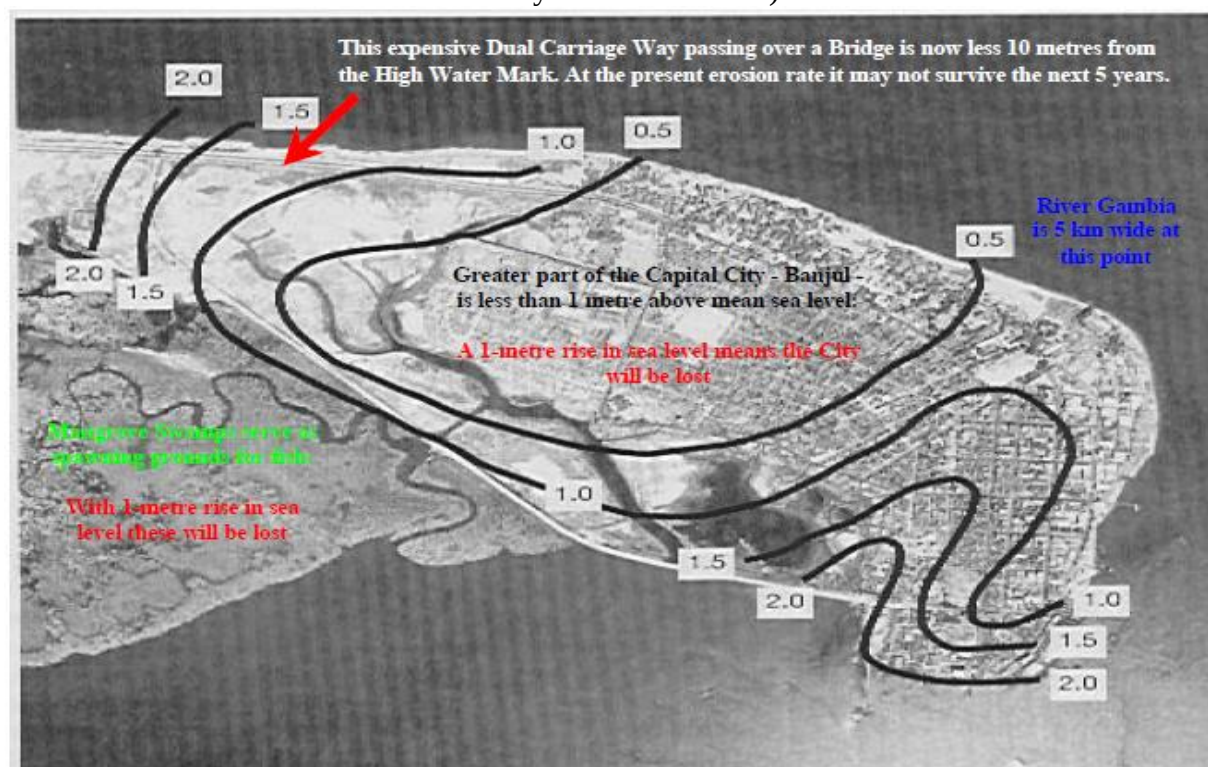
Environmental benefits include avoidance of water quality degradation, avoidance of biodiversity losses and the avoided use of chemicals for disease management. Disadvantages of aquaculture include conflict over resource usage, creation of a resource sink, disruption of social structure, and loss of traditional occupations. A continuous fall in market price, associated with oversupply problem may ultimately threaten the viability of the industry itself.

CHAPTER 4: TECHNOLOGY PRIORITISATION FOR COASTAL ZONE SECTOR

4.1 Key Climate Change Vulnerabilities in Coastal Resources Sector

Impacts of climate change on Coastal Zone: Brown et al. (2011) used the Dynamic Interactive Vulnerability Assessment (DIVA) model to project sea level rise in The Gambia at a significantly higher level than the IPCC predictions of 0.13 m in 2025, 0.35 m in 2050, 0.72 m in 2075 and 1.23 m in 2100 (in comparison with 1995 levels). Assessment results in the First National Communications suggest that about 92 km² of the coastal zone, including the city of Banjul (Figure 14) will be under water by 2100. The mangrove systems on St. Mary's Island and Kombo St. Mary and the strand plains from Barra to Buniadu Point will be lost. This large area of the mangrove systems serves as protection buffer against storms for most of the coastal settlements. The mangroves also serve as spawning grounds for fish species.

Figure 14: Orthophoto Map (contours in metres) of the Capital City of Banjul (the greater part of the City is below 1 metre)



Ecological impacts of beach erosion include the loss of nesting grounds for green turtles, and submergence of diverse habitats and ecosystems. Under continued sea level rise, present-day coastal wetlands will be gradually inundated resulting in the loss of mangrove and salt marsh vegetation. Absolute numbers and species of fauna associated with mangroves are expected to drop.

4.2 Decision context

The following discussions represent ongoing and planned climate change adaptation projects to reduce vulnerabilities and meet adaptation needs in the Coastal Resources sector of The Gambia. Relevant policies and strategies have been discussed under section 1.2.

- a) **GOTG/GEF/UNDP LDCF Coastal Resilience Project is one of the NAPA activities supported from the LDCF and implemented by UNDP and the Government of The Gambia.** The project is supporting The Gambia in enhancing resilience of coastal and vulnerable communities of The Gambia by reducing The Gambia's vulnerability to sea-level rise and associated impacts of climate change by improving coastal defenses and enhancing capacities of coastal communities. Due to the limited funding, the infrastructure and resilience component of this project is limited to the hotel areas on the Kololi Beach Area. The project plans to construct breakwater systems along the stretch of the hotel areas.

The project is also strengthening livelihoods of coastal communities at risk from climate change. The combined effects of sea level rise and changes in upstream river discharge, erosion of coastal embankments and changes to natural sediment dynamics pose a serious threat to the natural resource base and livelihood opportunities of coastal communities. In addition to recurrent and rapid onset of extreme events (i.e. flash flooding), The Gambia's coastal zone is being confronted with a range of "creeping" climate risks, such as increasing salinity level trends in coastal freshwater resources, growing drainage congestions, dynamic changes in coastal sediment dynamics and morphology and a decline in the functioning of protective ecosystems (e.g. mangroves). Given the lack of institutional capacity to systematically identify and address climate driven changes in risk patterns, the Government of Gambia is proposing a project to reduce the vulnerability of coastal communities to climate change-induced risks in 5 districts (Kotu, Tanji, Bintang, Darsilami and Tendaba).

- b) GOTG/WB/AfDB Pilot Programme for Climate Resilience (PPCR) is entitled ***"Climate Proofing of the Urban and peri-urban infrastructure in the Brikama and Greater Banjul Areas of The Gambia."*** Two components of the PPCR are relevant and are being implemented within an area covering from the shoreline to about 30kms inland.

One component will develop climate-proof public works infrastructure (roads, bridges, communication, etc.) in Brikama and Greater Banjul Areas. The objectives of this component include (a) creation of enabling environments and institutional structures for effective management of climate sensitive infrastructure; (b) increase resilience of transport, communication and other infrastructure in Brikama and Greater Banjul Areas; and (c) increase resilience of renewable energy power generation facilities and infrastructure. The outcomes will include improved resilience of climate change vulnerable infrastructure in Brikama and Greater Banjul Area.

The objectives and outcomes will be achieved through (a) integration of climate change in the Transport and Communication policies, regulations, strategies and plans and take into

consideration the land use and long term transport needs; (b) improving the climate change resilience of the Kombo Coastal Roads through rehabilitation and adjustment to the projected climate change scenarios; (c) establishment of road hierarchy, demarcation intersection priorities and road sections for pedestrians and the various categories of transport (bicycles, cars, buses, transect.); (d) development and implementation of a Drainage Master Plan for Brikama and the Greater Banjul Areas; and (e) build and strengthen the capacities of local contractors, tertiary institutions and youths in labour based technologies for execution and maintenance of public works and infrastructure.

A similar component of the project addresses the climate resilience of public and commercial buildings in Brikama and Greater Banjul Areas. The objective of this component is to increase infrastructural resilience of public and commercial buildings. The major outcomes include (a) climate change integrated policies and regulations that are applicable in planning and decision making at the Municipal Councils; (b) communities are aware and do apply the climate change integrated policies and regulations; and (c) public and commercial buildings are resilient to the adverse impacts of climate change.

The objectives and outcomes will be achieved through the (a) assessment of the location and structural conditions of all public and commercial buildings and related infrastructure in the Brikama and Greater Banjul Area (GBA); (b) updating of the environmental and climate change impact assessments of these infrastructure by considering their current and future vulnerabilities to climate change; (c) development of a strategy and action plan to address the negative impacts on the structures; (d) updating and integration of climate change measures and strategies into the national and sub-national policies and regulations for proper city and municipal planning; and (e) updating and integrating climate change into national and sub-national building and municipal plans containing building codes, set back regulations, etc.

4.3 Overview of Existing Technologies in Coastal Resources Sector

The coastal zone of The Gambia is the home to the majority of the population which continues to increase and is being reinforced by rural-urban migration. These populations, their settlements and livelihoods are exposed to sea-level rise and heavy precipitation events. Exposure to flooding (both coastal and inland following heavy precipitation) and storm damage is high in the informal housing in the Banjul and Bacau, and the Ebon Town, Jeshwang, Tallinding Kunjang and Fagikunda settlements where housing tends to be of poor quality and is easily damaged or destroyed.

Implementation of some climate change adaptation options and technologies in the coastal zone has been conducted since the colonial period but has met with serious challenges that include inadequate financial capacity and technical capacity to identify most appropriate measures to address sea level rise and coastal erosion.

Sea walls (Figures 15a & b) made of concrete or rock, are used to protect settlements and property against erosion or flooding. Modern seawalls aim to destroy most of the incident wave energy, resulting in low reflected waves and much reduced turbulence and thus take the form of sloping revetments. Sea walls can cause beaches to dissipate rendering them useless for beach goers. Their presence also scars the very landscape that they are trying to protect. Sea walls are probably the second most traditional and longest methods used in coastal management in The Gambia. Sea walls were used during the colonial period to protect some sections of the city of Banjul.



Figure 15a: Interlocking Sea Wall



Figure 15b: Sea wall or Bulkhead similar to one at Kairaba Beach Hotel

Groynes are common in The Gambia and have done well in the past. They are wooden structures but can also be made of concrete and/or rock barriers or walls perpendicular to the sea (Figure 16a & b). Beach material builds up on the updrift side, where littoral drift is predominantly in one direction, creating a wider beach, therefore enhancing the protection for the coast because the sand material filters and absorbs the wave energy. However, there is a corresponding loss of beach material on the downdrift side, requiring that another groyne to be built there. Groynes are extremely cost-effective coastal defence measures, requiring little maintenance, and are one of the most common coastal defence structures. Lack of wood for their construction has limited their use but this can be overcome with the use of concrete, which is relatively more expensive.



Figure 16a: Groynes made out of wooden planks

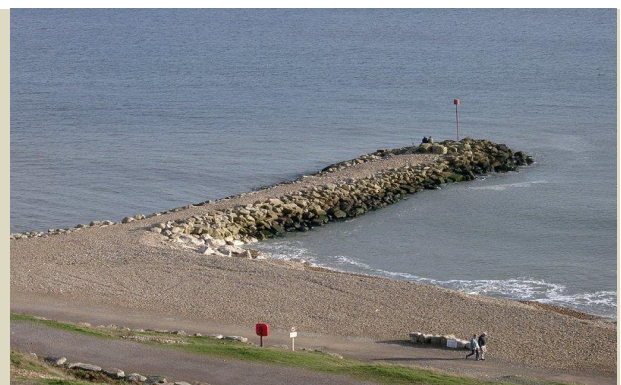


Figure 16b: Groynes made out of rocks and concrete

Revetments are constructed of upright blockades (Figure 17a & b), built parallel to the sea on the coast, usually towards the back of the beach to protect the structures and property beyond. Waves break against the revetments, which dissipate and absorb the energy. Since the wall greatly absorbs the energy instead of reflecting, it erodes and destroys the revetment structure; therefore, major

maintenance will be needed within a moderate time of being built, this will be greatly determined by the material the structure was built with and the quality of the product. In late 1990s, Local Leaders and elected representatives from the city of Banjul and surrounding settlements mobilised communities on self-help bases and constructed revetments on the beach to protect the Muslim cemetery of Banjul. Boulders were used but these were just dumped on the shoreline without further stabilization. These revetments were short lived because they were poorly constructed on a very dynamic sandy beach. Sea waves mined the sand under the boulders and washed away the boulders into the sea.



Figure 17a: Revetments constructed out of Boulders



Figure 17b: Armorloc Concrete Revetment

Sand management – Beach Nourishment: In 2003, the Government of The Gambia secured a loan of US\$ 20 Million from the African Development Bank (AfDB) in the efforts to address climate change induced erosion along the coast. The Government of The Gambia opted to use the loan for a soft-engineering approach to preserve the aesthetic integrity of the beach, by dredging offshore sand to create a 100-metre-wide beach. Within two years, half the sand had been lost, and in 8 years, the sea was less than 25 metres away today the sea is less than 20 metres away from the Kairaba Beach Hotel again (see Figures 18a to 18f below). A bitter lesson of mal-adaptation has been learned but the good thing is that capacity is slowly being built.



Figure 18a: Open and Sheltered Coastal Zone of The Gambia



Figure 18b: An attempt to protect the Senegambia Beach Hotel against acute erosion, using sandbags



Figure 18c: Kololi Beach Area in 2002 before Nourishment



Figure 18d: 100metre-wide nourished Kololi Beach Area in 2003



Figure 18e: Kololi Beach Area in 2010 – 7 years after nourishment



Figure 18f: Kololi Beach Area back to where it was before nourishment

Under the same project innovative sand management was applied to the sand bars (Figure 19a and 19b) between Oyster Creek Bridge (Sarro) and the city of Banjul to nourish that sector of the coastline. The sand appears to be holding but construction of sand stabilization structures such as groynes would give a longer life span to the nourished beach.



Figure 19a: The capital city of Banjul is less than 1metre above water and will be inundate with 1 metre ASLR



Figure 19b: Mangrove Swamps serve as Fish Spawning Grounds will be lost even with less than 1 metreASLR

Offshore breakwaters (Figure 20) are constructed of enormous concrete blocks and natural boulders that are sunk offshore to alter wave direction and to filter the energy of waves and tides. These are offshore breakwaters facilitating the breaking of the waves further offshore and therefore reduce their erosive power. This leads to wider beaches, which absorb the reduced wave energy,

protecting infrastructure and property behind. Breakwater systems do not exist in The Gambia. However, with the failure of the beach nourishment at the Kairaba and Senegambia beach areas, it is now planned to build offshore breakwaters to protect the coastline and beach around those areas. This decision also arose from a feasibility study under the GOTG/GEF/UNDP LDCF NAPA project on the coastal zone which concluded on the viability of the technology in reduction of erosion on the shoreline.



Figure 20: Examples of Breakwater Systems

4.4 Adaptation Technology Options for Coastal Resources Sector and Their Main Adaptation benefits

Table 6 below shows a long list of climate change adaptation options and corresponding technologies to implement the options. This list was developed by the National Adaptation Consultant through a desk review of existing climate change strategic documents and existing and proposed climate change related programme and project documents.

Table 6: Long List of Climate change adaptation options and technologies in the Coastal Zone

Document	Adaption Options identified	Adaptation Technologies
National Adaptation Programme of Action; First National Communications of The Gambia; Second National Communications of The Gambia	Innovative sand management on the coastal zone and the construction of shoreline stabilization structures such as groynes, revetments, breakwater systems or sea walls	1. Sand management 2. Groynes 3. Revetments 4. Breakwaters 5. Seawalls
	Development and implementation of the Integrated Coastal Zone Management Plan.	6. Policy and Plan
	Construction of flood-proof housing	7. Flood-proofing
	Increasing fish production through aquaculture and conservation of post harvest fishery products	8. Aquaculture
Gambia's Pilot Programme for Climate Resilience (PPCR)	Climate Proofing of the Urban and peri-urban infrastructure (Water supply, Public works infrastructure and Public and Commercial Buildings)	9. Climate proofing

4.5 Criteria and process of technology prioritisation

In an effort to prioritize the technologies selected for the coastal resources sector, the stakeholder team and the National Adaptation Consultant identified and agreed to the criteria shown in Table 7 below.

Table 7: List of criteria, their categories and the allocated weights used in the prioritization of climate change adaptation technologies for the Coastal Resources sector

Criteria	Criterion	Criteria category	Unit Chosen	Value Preferred (High, Low)	Allocated Weights in percentage (Social, 35%, Economic 30% and Environmental 35%)
1	Area protected	Environmental	Ratio	High	35%
2	Population protected	Social	Number of Persons	High	10%
3	Values protected	Economic	Index	High	10%
4	Cost of Intervention	Economic	GBP	Low	10%
5	Operations and maintenance costs	Economic	GBP/annum	Low	10%
6	Creation of Employment	Social	Ordinal	High	10%
7	Resettlement/Migration	Social	Ordinal	Low	5%
8	Health status	Social	Ordinal	High	10%

Eight criteria were identified and these were categorized as social (4), economical (3) and environmental (1) which were allocated weights as 35%, 30% and 35% respectively. Protecting the most important areas of the coastal zone was the preferred criteria and all the weights allocated to the environment category were allocated to the criteria of ‘area protected’. Protecting the most vulnerable area of the coastal zone will also protect the population, the infrastructure, the value of the built area, mitigate migration and resettlement and also address other potential social impacts such as health.

4.6 Results of technology prioritisation for the Coastal Resources sector

Applications of the criteria, the units and weights to the adaptation technology options produced the following ranking of the seven technology options in Table 8 below. The highest ranked technology option is Sustainable sand management (69) followed by Breakwater systems (68) and Groyne systems (64). Factsheets on these three priority technologies (Sustainable sand management, Breakwater systems and Groyne systems) can be found in Annex I and a brief description of them follows below.

Table 8: Prioritized and Ranked Technologies for the Coastal Resources Sector

Rank	Option	Weighted Score
1	Sustainable Sand Management	69.3
2	Breakwater Systems	68.1
3	Groyne Systems	64.4
4	Wetland Management	53.7

5	Flood proofing and resilience	47.3
6	Revetment Systems	23.7
7	Seawalls	14.8

4.6.1 Sustainable Sand Management

Sustainable sand management is one of a comprehensive approach to advance sustainable soft and hard coastal engineering measures at strategic locations of the coastal zone of The Gambia that is vulnerable to rising sea levels and coastal erosion. Sustainable sand management, including beach nourishment is a well recognized in The Gambia and deemed to have made positive impacts in the beach restoration system. Beach nourishment or replenishment (Figure 21a) is one of the most popular soft engineering techniques of coastal defense management schemes. This involves importing alien sand off the beach and piling it on top of the existing sand. The imported sand must be of a similar quality to the existing beach material so it can integrate with the natural processes occurring there, without causing any adverse effects. Beach nourishment can be used alongside the groyne schemes. The scheme requires constant maintenance.

In 2003 and 2004, beach nourishment was used around the Greater Banjul area to reclaim significant areas lost to erosion. About 1,400,000m³ of offshore dredged sand was used along a stretch of approximately 3 km to protect the capital city, cemeteries and the main Highway linking the Capital city of Banjul to the rest of the country. The beach nourishment at Kololi (Senegambia and Kairaba Beach Hotels, Figure 21b) was done with about 10⁶m³ of offshore dredged sand. The nourished beach at this site decreases at a rate of 2m annually due to increased wave energy (GoTG/GEF/UNDP, 2012).



Figure 21a: Beach Nourishment device

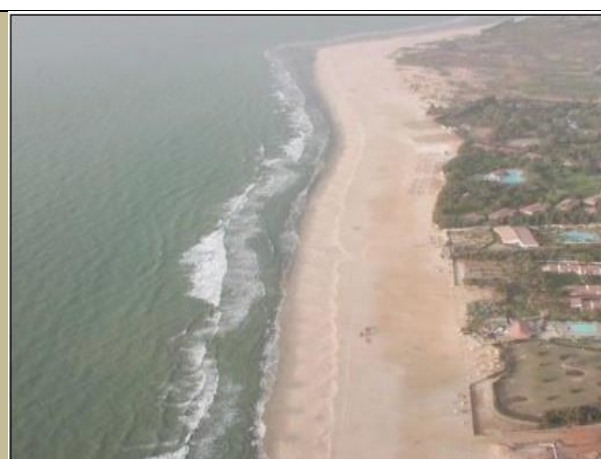


Figure 21b: Aerial view of Kairaba and Senegambia seafront after completion of beach nourishment project. Beach face is 150 metres wide at high tide.

Where the nourishment is accompanied by well designed shoreline stabilization schemes it has helped stabilize the coastal zone severely threatened by coastal erosion in the long term. This is the case at the Cape Point in Bakau. However, where the shoreline stabilization schemes are absent the nourishment measure has serious shortcomings and has actually led to more coastal erosion. This is the case at the Kairaba and Senegambia hotel areas in Kololi. These shortcomings of the 2003/2004 beach nourishment project are being corrected under the GoTG/GEF/UNDP LDCF

NAPA project using the proper engineering design with 50-year design standard to further ensure sustained benefits to future generations. The element of sustainable sand recharge involved with the scheme will also bring much needed recreational, aesthetic and touristic benefits.

4.6.2 Breakwater systems

Breakwaters are segmented, shore parallel structures built along the upper beach at approximately high water mark. They are normally built of rock, but can be formed of concrete armour units. Breakwaters reduce the energy of waves reaching the shoreline, but do not completely isolate dunes from the natural beach processes. The structures act as a direct barrier to waves, but at very high water levels they allow some overtopping. The gaps between segmented structures allow some wave energy to reach the upper beach and dune face, but this is dissipated by refraction and diffraction. Erosion may continue in the lee of the gaps leading to formation of an embayed shoreline as sand moves into the shelter of the structures. The width of the upper beach along the embayed shoreline may increase, providing improved recreation. New fore dunes may develop in the lee of the breakwaters. The structures allow natural beach-dune processes to continue, albeit along a modified shoreline. Existing dune habitats and land forms may be retained and/or enhanced in the areas behind the structures (SNH, 2011).

Costs for breakwater systems depend on structure dimensions and spacings. They can be heavily influenced by the availability of suitable rock (or other material), transport and the costs of any recycling or nourishment. Rock structures can be assumed to have an unlimited life with respect to economic assessments.

Breakwater systems have high impacts on shoreline processes, intertidal habitats and landscape systems, and may be unacceptable in environmentally sensitive areas. Erosion in the lee of the gaps may well continue for several years after construction while a new beach plan shape develops. On frontages affected by long-shore transport the breakwaters may reduce drift rates, resulting in the erosion of downdrift stretches of coast, but helping to stabilise the updrift shore. Where the nearshore waters tend to be silty, the breakwaters may encourage lee-side deposition of mud leading to both unwanted odours and unsafe beach areas. Other lee side deposits may include sea weed and jetsam from ships (plastic containers, nets, rope, etc). Wave induced currents around the ends of breakwaters can be locally strong and a danger to beach users (SNH, 2011).

4.6.3 Groyne Systems

Groynes are wooden, concrete and/or rock structures built perpendicular to the sea. They are cross-shore structures designed to reduce long-shore transport on open beaches or to deflect near-shore currents within an estuary. On their own, they will cause down-drift erosion as beach material is held within the groyne bays (SNH, 2011). Beach material builds up on the updrift side, where littoral drift is predominantly in one direction, creating a wider and a more plentiful beach, therefore enhancing the protection for the coast because the sand material filters and absorbs the wave energy. However, there is a corresponding loss of beach material on the downdrift side, requiring that another groyne to be built there. Beach recycling or nourishment is normally required to maximize the effectiveness of groynes.

Groynes are extremely cost-effective coastal defense measures, requiring little maintenance, and are one of the most common coastal defense structures. They are common in The Gambia and have done well in the past. Lack of wood for their construction has limited their use but this has recently been overcome with the use of concrete and rock structures. The groyne systems in The Gambia have been constructed out of matured rhun palm trees which are suitable for saline conditions. There is acute shortage of these trees in The Gambia but there is abundant supply in neighbouring Senegal and Guinea Bissau. Business entities can take advantage of the market potentials. Concrete groynes also provide business entities with potential to procure concrete materials from the construction of the groynes.

CHAPTER 5: TECHNOLOGY PRIORITISATION FOR WATER RESOURCES SECTOR

5.1 Key Climate Change Vulnerabilities in Water Resources Sector

Water resources in The Gambia include surface and groundwater systems. Much of The Gambia is low-lying in flood-prone areas. It is projected that increased PET as a result of future climate change, combined with construction of dams in upper Gambia River, will result in reduced freshwater recharge downstream, causing hyper salinity in mangrove and other wetlands along the river's estuary and coastal zone. Hypersalinity in rice growing swamp areas could negatively impact the food production and livelihoods associated with rice production. Based on the maximum expected increase in open water evaporation, in conjunction with the mean ratio of actual to potential evapotranspiration at Sambangalou and Gouloumbo, it is projected that there will be a 3% reduction in groundwater recharge, by the year 2075.

As a direct consequence of sea level rise, peak flows are expected to decrease in magnitude and occur later than under present sea level. Under projected sea level rise, the saline front (salt concentration = 1g/l) is expected to migrate landward/upstream of its present upper limit around Kuntaur (254 km). Oceanwards, the duration of salt-water transgression will be increased, but the perennial nature of the freshwater flow regime will be enhanced the further one moves in the direction of the river's headwaters. Under the projected rise in mean sea level, it is observed that maximum saline intrusion length increases by a mere 40 m/year.

The coastal communities, their settlements and livelihoods are exposed to sea-level rise, heavy precipitation events and serious health risks associated with flooding, as flooding often contaminates drinking water supplies and create conditions conducive to pathogens. Reduced rainfall and thus reduced recharge of the groundwater and surface water resources result into intrusion of saltwater into water sources, particularly on the Kombo Peninsular. Some of the water points have been abandoned; in some areas it has become expensive to sink water points as one has to dig deeper and maintain a deeper water column in the water points to allow availability of water for the whole year.

Increase strength and severity in windstorms and flash floods have been observed and they cause the most damage to property in The Gambia. Each year these hazards result in significant infrastructure damage, injuries and fatalities, and loss and damage to agricultural crops. Climate-related illnesses such as malaria which peaks in the rainy season (July-October) and diarrhoeal diseases which increase during the monsoons due to inadequate water handling practices and environmental sanitation exacerbated by uncontrolled runoff and flooding, are likely to be impacted by climate variability. The flooding also increases exposure to malaria and other waterborne and water contact diseases, which can quickly affect many people due to population density.

5.2 Decision context

The following discussions represent ongoing and planned climate change adaptation projects to reduce vulnerabilities and meet adaptation needs in the Water Resources sector of The Gambia. Relevant policies and strategies have been discussed under section 1.2.

- a) **GoTG/IDB Rural Water Supply Project (2009 – 2012):** All rural water supply projects, including the GoTG/IDB project, conform to set policies, guidelines and criteria for water supply in rural areas as set by the Government of The Gambia and operated through the Department of Water Resources. Hand-dug wells are provided to communities with a population of 1000 people or less. A population of 500 people benefits from a hand-dug well fitted with a hand-pump (Figure 22) while a population of greater 500 to 1000 people benefits from a hand-dug well with two hand-pumps.



Figure 22: Hand dug well fitted with hand pump for a population of about 500 persons

Solar water pumping systems are very successful in the Gambia, and have become the preferred technological option of the Government. They are also reliable and cost effective. But given their high capital cost, they can only be justified for villages with a population above 1,000 people. The demand for these solar systems by far exceeds the supply, and DWR has had to set criteria to select villages that qualify for a solar system to ensure maximum social and economic benefit from the available financial resources. All recent donor projects, financed by the EU, IDB, Saudi Fund and JICA have partly implemented their project using solar system technology.

The GoTG/IDB project has provided 90 boreholes with hand pumps and 10 boreholes with solar and reticulation systems (see Figures 23a – f below)



Figure 23a: Borehole drilling equipment for water supply



Figure 23b: Solar pumping system for rural water supply displaces diesel fuel and thus reduces greenhouse gas emissions



Figure 23c: Before construction of water supply system



Figure 23d: After construction of water supply system

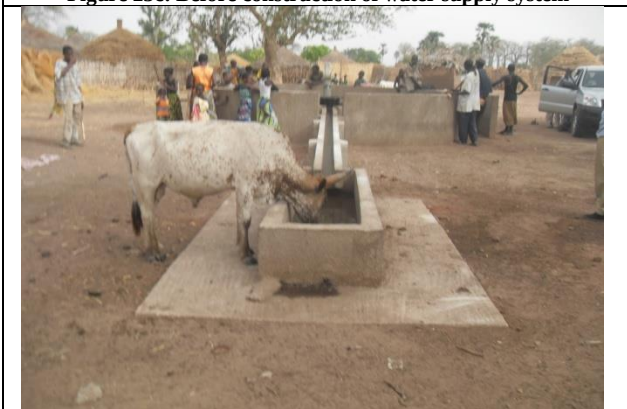


Figure 23e: Infrastructure for livestock watering



Figure 23f: Trained Water Committee responsible for the management of village water facility

- b) **GoTG/AfDB Water Sector Reform Project**(2010 to 2015) was supported by the Africa Water Facility and has the objectives to (a) support the establishment of IWRM in The Gambia in line with the National Water Policy and the IWRM Roadmap, and (b) develop the legal and institutional arrangements for the implementation of the water policy. The project components include improvement of water resources data and knowledge base and groundwater assessment. Groundwater assessment covered the whole country and the study identified areas of potential risk, produced a revised hydro-

geological map of The Gambia, and produced a groundwater model for areas of potential irrigation and water supply development. The major output is the sustainable management of groundwater systems in the country.

- c) **GoTG/AfDB Rural Water Supply and Sanitation Project (GoTG/AfDB, 2011)** has the goal of “effective and sustainable management of water resources and improved climate risk management to support socio-economic development and environmental sustainability in The Gambia”. The objective of the project is to increase access to safe drinking water and improved sanitation in the rural areas of The Gambia from the current level of about 70% to 72% for water supply and from 40% to 44% for sanitation by 2015. It will provide safe drinking water and improved sanitation to an additional 65,000 people in rural Gambia.

The exclusive use of solar energy technology in water supply systems provides mitigation potentials. When the use of solar energy for pumping water is blended with landscaping of the infrastructure through planting of vegetation, greater environment benefits can be derived including addressing climate change.

The water supply and sanitation component comprises of the provision of new boreholes installed with solar powered water supply systems, and rehabilitation and upgrading of existing water supply facilities in the project areas. A total of 18 new boreholes (6-8-inch diameter) were drilled and 4 existing boreholes were rehabilitated. These were fitted with stand-alone solar powered pumping units, elevated water tanks, distribution network and public stand-taps and are supplying piped water to medium and large size rural communities (with greater than 1000 people).

Selection of sites for the new water schemes and those to be rehabilitated and upgraded were done on the basis of technical and socio-economic guidelines provided by the Department of Water Resources. The main criteria used for selection of villages to benefit from new facilities are: (a) population exceeding 1000 people; (b) previously installed water supply systems are well maintained; (c) ability of villagers to deposit at least D25,000 (25 thousand Dalasis) as part of the maintenance fund; (d) willingness of villagers to provide land for the borehole, solar panel and tank area; and (e) villages that are not more than 1.5 km apart are clustered and supplied from one system. The selection of villages to benefit from upgrading is based on (a) communities that experienced rapid population growth, since the systems were installed and the systems can no longer meet the water demands of the population; (b) poor water quality due to high presence of iron or manganese; and (c) deep water table that limits the ability of the hand pumps to lift water.

- d) **GOTG/WB/AfDB Pilot Programme for Climate Resilience (PPCR)** is entitled *“Climate Proofing of the Urban and peri-urban infrastructure in the Brikama and Greater Banjul Areas of The Gambia.”* The water supply, sanitation and waste management component of the PPCR has objectives that include: (a) integration of climate change in the existing water, sanitation and waste management policies, strategies and

plans; (b) development of climate change sensitive guidelines and codes for improvement of infrastructure and services particularly in vulnerable coastal settlements; and (c) improvement of urban and peri-urban water supply infrastructure to enhance portable water availability. It is proposed to construct and manage climate change resilient water supply infrastructure (standpipes, boreholes, wells, etc.) and develop and adopt the policy of increased water columns from 4 meters to 6 meters.

The major outcomes will be (a) a climate change sensitive National Water Policy, Law, Strategy and Action Plan; (b) greater water security for communities especially in the Coastal Zone; (c) water resources infrastructure that is protected from and made resilient to extreme climate events; (d) evidence of increased access to potable water; (e) waterborne diseases are brought under control through effective surveillance and effective and timely action; (f) integrated water management policy; and (g) more sustainable and climate resilient settlements.

Similar closed projects are shown in Table 9 below.

Table 9: Similar projects implemented in the country

Funding Source	Project Name	Description	Period
Saudi Fund	Saudi Sahelian Programme (SSP) Phase 4	Rural water supply and sanitation for target population of 100,000	2006 - 2009
EC/EDF-9	Rural Water Sector Support Programme	Rural water supply and sanitation (wells, boreholes and solar systems)	2006-2010
EC / EDF-8	Regional Solar Programme phase II	Rural water supply(boreholes fitted with solar systems)	2002 - 2009
JICA	Integrated Water Use Project Phase 2	20 new solar powered water systems and converting 9 diesel powered systems to solar power	2005 - 2008
JICA	Integrated Water Use Project Phase 3	15 new solar powered water system and converting 3 diesel powered system to solar powered	2009 - 2012
UNDESA	Managing Water and Energy Services for Poverty Eradication	Expansion and Extension of Rural Water Supply Systems schemes to cater for horticultural activities in 5 villages	2004 - 2008
AfDB	Water Supply and Sanitation Study for The Gambia	Master Plan for Water Supply and Sanitation in major urban areas and detailed design for priority areas	2006 - 2008

5.3 Overview of Existing Technologies in Agriculture Sector

Water conservation is a composite of technologies that include reduction in water losses from leakage, decrease in water demand, increasing water use efficiency, and effective management of water supply systems using efficient institutions such as Village Water Committees (VWCs). In the municipal water supply sector, activities include sensitization campaigns for people to be reporting leakages, replacement of decades-old asbestos pipes and execution of leakage reduction programme. In addition the public utility will champion the replacement of flush tanks used in hotels with water-saving devices, and provide price incentives to major industrial consumers for using water saving production units and processes. Expansion of production capacity is thus

expected to be less frequent and on a lower scale resulting in significant reduction of supply augmentation investment and operational expenditure.

In irrigated agriculture, the shift from traditional flood irrigated rice production to system of rice intensification is expected to save water consumption per crop cycle by 40%. Assets needed for implementation of water conservation under the adaptation scenario include leakage detection equipment, repair toolkits, maintenance materials, retrofit equipment, and utility and specialized transport (Njie and Jarjusey, 2011).

Water harvesting from rooftops and surface runoff are the two technologies considered in this report. Both are applied in The Gambia. Rainwater harvesting is simply the collection and distribution of natural rain water for domestic and irrigation applications. The simplest system in The Gambia uses any type of movable container available in the house to collect rain water running from the roof of the house.

Rainwater harvesting from rooftops has long been practiced in rural Gambia especially in the Saloum districts of the Central River Region (CRR). It has gradually expanded to the Kombos and the Kanifing Municipality. With the erratic rainfall since the 1970s and the current impacts of climate change, rainwater harvesting from rooftops is beginning to be popular and acceptable to the communities as additional sources of water supply for domestic use. Further improvement of the rainwater harvesting system included the construction of rudimentary gutters and concrete tank to collect the water. Collection using movable containers and rudimentary gutters and concrete tank is not free of pollutants.

Using rainwater harvested from rooftops enables reduction of the quantity of water obtained from the main supply of the National Water and Electricity Corporation (NAWEC) in the urban areas and the Rural Water Supply Division of the Department of Water Resources in the rural areas. Savings in water bills are realized that can be utilized for other financial needs of the households. Due to increased aridity and the reduction of the quantity of both atmospheric, surface and groundwater resources, the current rainwater harvesting systems from rooftops are becoming inadequate in both the size of the equipment and the quantity of water collected and delivered. Rainfall in The Gambia is also reducing in terms of quantity received at the surface. Rainfall in terms of quantity and frequency is erratic and climate change will exacerbate this situation.

Rainwater harvesting from runoff is particularly relevant in The Gambia where the little rainfall received in the three months of the rainy season is usually very intense and most of it is lost through runoff. During the Sahelian droughts of the 1970s and 1980s, animal watering was a serious challenge in The Gambia and the Sahel region as a whole. The Department of Livestock Services excavated sand from large areas of the ground to build reservoirs in which runoff water was collected and stored mainly for use for livestock watering.

The surface runoff water harvesting technology has the potential to increase the availability of water for various uses other than for livestock watering. The additional water will be useful in increasing livestock productivity, expanding horticulture, increasing the availability of protein

from fish and reducing conflicts due to transboundary movement of animals in search of water and pasture. A major challenge would be insufficient rainfall due to prolonged dry spell or drought during the rainy season. Soil type, texture and water retention capacity also limit the success of the technology. The current surface runoff water harvesting technology and techniques used in The Gambia are inefficient and need to be modernized for sustainability. However, the technology is now being used in countries such as Togo for various other purposes such as aquaculture and horticulture using small-scale irrigation systems. As in Sudan, the water can be used for human consumption after appropriate filtering (Government of Sudan, 2013).



Figure 24: Rainwater Harvesting from Runoff in Northern Togo

5.4 Adaptation Technology Options for Water Resources Sector and Their Main Adaptation benefits

Table 10 below shows a long list of climate change adaptation options and corresponding technologies to implement the options. This list was developed by the National Adaptation Consultant through a desk review of existing climate change strategic documents and existing and proposed climate change related programme and project documents.

Table 10: Long List of climate change adaptation options and technologies in the Water Resources Sector

Document	Adaption Options identified	Adaptation Technologies
National Adaptation Programme of Action; First National Communications of The Gambia; Second National Communications of The Gambia	1. Construction of flood-proof housing 2. Policy and institutional reforms in the water resources sector (e.g., relocation of abstraction points, changes in pumping policies of deep wells and boreholes, flow regulation, licensing and permits for withdrawal of river water for irrigation and increase water column in wells) 3. Improvement of Fresh Water Availability	1. Flood proofing 2. Relocation of water points 3. Increasing Water Columns in wells 4. Flow regulation 5. Irrigation
Draft Low Emissions Climate Resilient Development Strategy	4. A wise industrial policy with preference to new public and private investment that contribute to sustainable development and supported by public sector investments that develop the necessary infrastructure and provide access to basic energy and water and sanitation for the poor.	6. Water Resources software adaptation technologies (policy on PPI)
	5. Promote smart and sustainable agricultural production methods that have great mitigation and adaptation potential, particularly with regard to topsoil organic matter fixation, soil fertility and water-holding capacity, and increasing yields in areas with medium to low-input agriculture and in agroforestry.	7. Soil fertility management 8. Agroforestry
GoTG/AfDB Rural Water Supply and Sanitation Project	6. Increase access to safe drinking water and improved sanitation in the rural areas of The Gambia from the current level of about 70% to 72% for water supply and from 40% to 44% for sanitation by 2016; 7. Provide safe drinking water and improved sanitation to an additional 65,000 people in rural Gambia. 8. Provide 18 new boreholes to supply piped water to medium-large size rural communities (with greater than 1000 people) and installation of stand-alone solar powered pumping units, elevated water tanks, distribution network and public stand-taps. 9. Rehabilitate and upgrade 4 existing water supply facilities in the project areas to solar powered pumping units, elevated water tanks, a distribution network and public stand-taps.	9. Water facilities (boreholes and wells) 10. Fuel switching from fossil to renewable water pumping technologies

National Water Sector Reform Project	10. Revise the Water Bill of 2004 to provide legislation that fully incorporates the provisions of the new National Water Policy so as to establish IWRM in The Gambia; 11. Develop an institutional set up for water resources management in The Gambia; 12. Develop a water resources management strategy and implementation plan; 13. Develop and implement a water training programme for MoFWRNAM; 14. Rehabilitate and improve the hydrological, hydro-geological, meteorological and water quality monitoring networks in The Gambia; 15. Develop and implement a water resources management information system; 16. Conduct assessments of groundwater resources; 17. Develop and implement a water sector related communications strategy.	11. Water Resources software technologies (Act, Policy, strategies) 12. Early warning infrastructure 13. Groundwater studies
Gambia's Pilot Programme for Climate Resilience (PPCR)	18. Climate Proofing of the Urban and peri-urban water and sanitation infrastructure	14. Climate proofing

5.5 Criteria and process of technology prioritisation

To prioritize the technologies selected for the water resources sector, the stakeholder team and the National Adaptation Consultant identified and agreed to the criteria shown in Table 11 below. These criteria assist in assessing and comparing the benefits and costs of the implementation of the selected technologies selected for the water resources sector. The ordinal scale of 1 – 5 was used in the scoring of the technology options for each criteria. For the environmental and social categories of the criteria the score of 1 represents the least beneficial and 5 represents highest beneficial technology. For the economic category the reverse is true with 1 representing the highest cost and 5 the least cost in the implementation of the technologies.

The criteria categories (economic, environmental and social) were allocated weights with economic category being allocated a weight of 20, environmental category was allocated a weight of 30 and the social category was allocated a weight of 50. These weights of the categories were further allocated to the sub-criteria as shown in the last column of Table 11.

Table 11: List of criteria, their categories and the allocated weights used in the prioritization of climate change adaptation technologies for the Water Resources sector

Criterion		Criteria category	Unit Chosen	Value Preferred (High, Low)	Weight
1	Increased water productivity	Social	Ordinal	High	25%
2	Reduced pressure on ecosystem	Environmental	Ordinal	High	15%
3	Improved water quality	Environmental	Ordinal	High	15%
4	Cost of Intervention	Economic	Ordinal	Low	10%
5	Operations and maintenance costs	Economic	Ordinal	Low	10%
6	Creation of Employment	Social	Ordinal	High	10%

7	Health impacts	Social	Ordinal	High	15%
---	----------------	--------	---------	------	-----

Stakeholders involved in the categorization of adaptation technologies under the water sector highly preferred the social criterion of increased water productivity and allocated it the weighting of 25%. Determining and adopting the technology that meets the criteria and objective of augmenting productivity of water, particularly for human and animal consumption, will enable the partial fulfillment of the objectives of maintaining and/or improving the health status of the populations. With the accompanying sound and sustainable management of the water resources, the adoption and implementation of the technologies will reduce saltwater intrusion into aquifers and flooding of water points, thus improving the water quality. Water stress on ecosystems will be reduced under changing climate.

Keeping the cost of the interventions reasonable and the operations and maintenance as low as possible requires the use of local and readily available materials during the procurement and installation of new and/or retrofitting and replacement of existing equipment and infrastructure.

The design of new and the improvement and implementation of existing policies, regulations and strategies through integration and mainstreaming of climate change adaptation are soft but cost effective and sustainable pathways to addressing climate change impacts in the water sector.

5.6 Results of technology prioritisation

The agreed criteria and categories, the units and weights in Table 11 above are input into the worksheets of the MCA software and the calculations and ranking are performed automatically. Table 12 shows the ranking of the technologies identified for the water resources sector with Water Conservation, Relocation of Water Points and Aquifer Recharge being ranked as the highest priorities. These prioritized technologies are described in the following paragraphs and will be further subjected to analysis in the next stages of the TNA process.

Table 12: Ranking of the Adaptation Technologies for the Water Resources sector

Rank	Option	Weighted Score
1	Water Conservation	77.5
2	Relocation of Water Points away from saline and flooded areas	53.3
3	Aquifer Recharge	28.3
4	Water Harvesting from Rooftops	26.7
5	Water Harvesting from Surface Runoff	17.5

5.6.1 Water Conservation

Water conservation enhances freshwater availability through a composite of strategies and technologies that include reduction in water losses, decrease in water demand and effective management of water supply systems using Village Water Committees (VWCs). Water losses in

community water supply systems can occur during storage, transmission, or delivery through evaporation, leakage (often due to aging infrastructure), or improper, illegal, or uncontrolled use. Demand for water can be reduced and the efficiency of water use by households and commercial entities increased with the help of new technologies (e.g., no- or low-flow toilets, low-flow showerheads, reformulated manufacturing techniques), as well as policies (e.g., water tariffs, reduction of non-revenue water, integrated water resources management).

Among the biggest barriers to water loss reduction is the limited knowledge in the country on losses due to aging water distribution infrastructure, unauthorized access and illegal connections, cost-benefit analyses of repairs, and proper building or repair technologies. It is important to maintain accurate utility and customer meter data. A weak Village Water Committee poses the risk of poor management performance. Undue political influences and partisanship also limits the effectiveness of the Village Water Committee members in the execution of its duties.

Most of the community water supply in The Gambia comes from boreholes with piping to tap heads. Strategies for limiting water losses in distribution networks require improving O&M as well as replacing aging infrastructure. Recently, metering has been introduced for effective monitoring of usage and detection of wastage due to leakage. Stakeholders appreciate the introduction of some of these strategies. With some improvements (e.g., increases in the depth of boreholes, wells and reservoirs) climate change impacts such as decreasing water tables due to reduction in recharges can be accommodated. Number of technicians to maintain the reticulation systems will need to be increased substantially due to large number of retirees from the public service. Village Water Committees need capacity building on leadership roles and responsibilities, and financial management rules and procedures. These must be supported by an operational manual for leadership accountability and financial auditing. Public-private-partnerships need to be established and to encourage investment by the business sector.



Figure 25: Common sight of repairs of leakage due to aging infrastructure

Aging infrastructure is costly to repair or replace, leak detection and repair can also be costly depending on the size of the system. Covering or lining storage facilities to reduce evaporation is most cost-effective for small facilities. Lining canals is efficient but expensive, although costs vary from concrete linings, the most expensive option, to colmation, the least expensive. Climate change will affect the availability of water, thereby increasing its value and the economic benefit of strategies for reducing water losses.

Where water loss reduction offers financial benefits to the owners of water storage and distribution infrastructure, significant market potential exists for investment in materials and infrastructure for reducing water losses. Business entities can forge partnerships with the national water utility (NAWEC) for financing and maintaining some of the components of the water distribution systems such as leak reductions and through the partnerships the business entities receive a percentage of the profits and savings from the water utility. Reducing water losses can produce a number of co-benefits. Reducing the amount of water lost in transmission means that less water has to be pumped to deliver the desired volumes to the user locations. Energy will be saved in the process. The technology supports employment at the community through ensuring availability of water for off season farming activities. The technology requires low investment for capacity building of Village Water Committees. There will be reduced public and private expenditures on climate related disaster management through its support to building community resilience. Minimizing leaks in water distribution systems means that less pathogens and other contaminants can enter potable water supplies. Adequate water pressure is also maintained at water hydrants used by Fire Fighting Services to provide protection against fires. Reducing large-scale leaks will keep water tables from rising and causing damage to building foundations and other critical infrastructure, or creating seepage areas where mosquitoes and other disease-spreading pests may breed. Using Village Water Committees for provision of effective management of the water supply systems provides extra income for farmers' groups through increasing water availability for production and through improved management of water resources that supports improvement in water quality. The VWCs also develop market cooperatives that ensure effective marketing of members' produce and create opportunity for increased group and individual earnings at group and community level. Minimizing water losses means less pumping, reduced energy use and reduced GHG emissions. Reducing residential and commercial water use can ease pressure on ecosystems that provide surface water and create a number of other environmental co-benefits.

5.6.2 Relocation of Water Points

Key adaptation measures that are pertinent to addressing the climate change related impacts on the water resources status and management functions include resettlement of people or relocation of activities away from the flood plains (Njie, 2002) and (e) relocation of abstraction points (water wells and boreholes) to less saline areas (GOTG, 2007; Jarju, 2009). In the Kombo peninsula and along the estuary of the River Gambia up to about 195 km upstream, water wells and boreholes have been found to be too saline for human consumption and crop and livestock watering and are also frequently contaminated by surface flooding. These water points need to be plugged and

abandoned. Replacement boreholes need to be relocated and drilled within a safe distance of the abandoned saline locations and sources such as the sea and the shoreline. Relocation will include drilling the same number of water points or lesser number landward of the safe distance of 2 km (van Dongen, 2014). Relocation of water points will also meet the water supply side adaptation measures which include (a) the construction of new systems such as well fields and hand-dug wells; (b) modification of existing physical structures such as conversion of diesel powered water pumping systems to solar powered systems and (c) developing alternative management of existing water supply system, for example by changing operating rules, coordinating water supply/demand systems or conjunctive use of surface and ground water supplies. Relocation and modification of technologies will meet the water demand adaptation measures that include (a) conservation and improving efficiency, (b) technology change such as the use of solar power water supply systems in the rural communities and (c) market or price driven transfer activities. For examples, policies which involved metering, water pricing, as well as use of conservation methods, have been found to improve efficiency and promote reduced water loss through demand management. In rural Gambia, the communities have service contract with the companies for the operation and maintenance of solar water supply systems. Under this arrangement, community taps are metered and payment is based on the volume of water consumed. This has resulted to efficiency in water use because communities use pipe water supply for drinking and water from traditional wells for laundry and other domestic purposes. This reduces the stress on water withdrawals from the aquifers.

Cost is an important factor to consider in the relocation of water wells and boreholes away from flood-prone and saline areas. The estimated unit cost of drilling one borehole and installation of a solar-powered reticulation is about US\$42,000 for 1,000 residents, US\$56,000 for 2,000 residents and US\$120,000 for 5,000 residents. For a population of less than 500 residents a drilled or hand-dug well fitted with one handpump is estimated to cost about US\$10,000 and for a population of 500 to 1000 residents a dug or drilled well when fitted with two handpumps is estimated to cost US\$14,000. Operations and maintenance cost also vary with the size of the system. Funding can be available from domestic and international development partners

Economically, relocation of water points from flood and saline prone zones will promote and facilitate adaptation to the negative impacts of climate change, reduce the chances of households failing to access potable safe water supplies during floods; reduce the time lost traveling long distances to access good drinking water when the water point gets either damaged, contaminated or cannot be accessed because of the floods; and increase agricultural productivity and reduce pollution from saltwater. Socially, the spread of illness through the water supply is possible from the downward migration of contaminated flood water into domestic dwellings, farms and industry with private supplies. Environmentally, construction activities during the relocation of deep wells and boreholes will cause damage to soils and vegetation cover.

5.6.3 Aquifer Recharge

Under current climate variability certain parts of The Gambia are starved of freshwater supplies either due to reduced runoff or groundwater recharge. The water points (wells and boreholes) in these areas have either dried up and the water table has receded to a point where most of the time the water points remain dry or the freshwater is contaminated with intruding salt water flowing

from the sea. Artificial recharge of groundwater aquifer is important for the storage of surplus surface water due to excess stormwater runoff underground to serve growing populations demand for more water under a warming and drier climate as projected for The Gambia. The recharge is also useful in mitigating or controlling saltwater intrusion into coastal aquifers.

The artificial recharge techniques in common use include (a) infiltration basins and canals, (b) water traps, (c) cutwaters, (d) drainage wells or "suckwells", (e) septic tanks and effluent disposal wells, and (f) sinkhole injection technologies. Cutwaters can be used in rangelands, degraded lands, forests, and national parks and sinkholes can be used in residential areas to encourage infiltration of rain water into the ground and aquifers. Capital costs of these technologies vary from about US\$133 for water traps to US\$31,300 for basins and canals. Operations and maintenance costs also vary with technology.

Groundwater recharge produces a number of economic, social and environmental co-benefits. The recharge increases freshwater availability for agricultural activities particularly in horticulture which is practiced by women during the dry season. Income generated from horticultural activities is used to pay for school fees and for medical attention. Women also use some of the money to buy clothes to attend social gatherings.

Recharge methods are environmentally attractive and create a number of other environmental co-benefits. However, there are some environmental concerns. During the construction of water traps, disturbances of soil and vegetation cover may cause environmental damage to the construction area. There is a potential for contamination of the groundwater from injected surface water runoff, especially from agricultural fields and roads surfaces. Recharge can degrade the aquifer unless quality control of the injected water is adequate.

Replenishment and storage of rain and runoff water in underground aquifers of The Gambia using the technologies discussed have the advantages of (a) simple and appropriate technologies that can be easily understood and applied by both the technicians and the general population; (b) potential to capture, store and utilize a lot of the rainwater that falls and runs off to the sea during the wet season; (c) the recharge will significantly increase the sustainable yield of the two aquifers of the country; and (d) support the management of surface water runoff and thus reduce erosion, loss of top soil and sedimentation problems in farms and fish spawning grounds. Disadvantages include (a) recharge with effluents may not be culturally acceptable especially when the groundwater stored is used for agriculture and livestock watering; (b) in the absence of financial incentives, laws, or other regulations to encourage landowners to maintain drainage wells adequately, the wells may fall into disrepair and ultimately become sources of groundwater contamination; and (c) where significant volumes of water are not available to inject into the aquifer, groundwater recharge may not be economically viable. This last disadvantage makes aquifer recharge option clouded with doubt under the projected climate change in The Gambia.

CHAPTER 6: SUMMARY AND CONCLUSIONS

6.1 The TNA process

The TNA development process started in August 2015 with a Technical Mission to The Gambia in March and April 2015 which initiated the engagement of stakeholders. The National Coordinator and two National Consultants, one on Adaptation and the other on Mitigation, were contracted. During the TNA Project Inception workshop, the membership of the National Project Steering Committee was agreed. Stakeholders agreed to work on Agriculture, Coastal Resources and Water Resources sectors in assessing adaptation technologies. The National TNA Committee constituted two thematic (mitigation and adaptation) working groups to engage relevant stakeholders in the TNA process. The Adaptation Sectoral Working Group includes persons drawn from public and private sector departments. Thus, the relevant TNA institutional structure has been put in place and the capacities of key national actors have been built and/or strengthened.

The TNA Adaptation Consultant also participated in the regional training workshop on the TNA process held in Arusha Tanzania in June 2015. The National Consultant consulted with other stakeholders to collect data and information necessary for the technology assessment process. The National Consultants on Adaptation and Mitigation Technologies jointly provided training to key actors and members of the Working Groups that enabled them to perform the tasks including the development of national circumstances of the country. The consultation and training enabled the understanding of the trends in the current and future climate, determining the level of vulnerability of the national economy and the various sectors to climate change, and the identified adaptation strategies and actions in published national strategic document such as the INDC, the NATCOM and NAPA.

The TNA process and stakeholder engagement are expected to continue beyond the production of this Report of the Technology Needs Assessment of The Gambia. Stakeholders will be continuously engaged in the production of the rest of deliverables of the TNA Project including a report on the Barrier Analysis and the Technology Action Plan (TAP).

6.2 Technology Characterization and the Criteria utilized in the process

The Adaptation Sectoral Working Group worked with the National Consultant to conduct the technology characterization and prioritization for the Agriculture, Coastal Resources and Water Resources sectors. Based on the review of national climate change strategic documents, key climate change vulnerabilities and ongoing and planned adaptation activities for the three sectors are determined. The adaptation technologies needed to implement these adaptation actions were identified, and the methodologies and tools to characterize and prioritize the adaptation technologies were determined. The tools include the Multicriteria Analysis (MCA) software. To prioritize climate change adaptation technologies for the three sectors, the Adaptation Working Group and National Consultant identified criteria, units and weights (Table 13 below) and inputted them in the MCA worksheets.

Table 13: List of criteria, their categories and the allocated weights used in the prioritization of climate change adaptation technologies for the sectors

	Agriculture Sector			Coastal Resources Sector			Water Resources Sector		
	Criterion	Criteria category	Weights	Criterion	Criteria category	Weights	Criterion	Criteria category	Weight
1	Increased productivity	Social	25%	Area protected	Environmental	35%	Increased water productivity	Social	25%
2	Biodiversity Conserved	Environmental	15%	Population protected	Social	10%	Reduced pressure on ecosystem	Environmental	15%
3	Total Cost	Economic	10%	Values protected	Economic	10%	Improved water quality	Environmental	15%
4	Return on Investments	Economic	25%	Cost of Intervention	Economic	10%	Cost of Intervention	Economic	10%
5	Creation of Employment	Social	10%	Operations and maintenance costs	Economic	10%	Operations and maintenance costs	Economic	10%
6	Health status	Social	5%	Creation of Employment	Social	10%	Creation of Employment	Social	10%
7	Applicability by farmers	Social	10%	Resettlement/Migration	Social	5%	Health status	Social	15%
8				Health status	Social	10%			

These criteria, their categories and weights are discussed under sections 3.5, 4.5 and 5.5 respectively. Under agriculture, stakeholders attached highest preference and allocated the highest weight to the social category of criteria. Increased productivity under agriculture means that the application of the technologies must lead to increased yields, income and capability to easily meet the social needs of the family including education and health. Protecting the most important areas of the coastal zone was the preferred criteria which will also translate to the protection of the population, the infrastructure, the value of the built area, mitigate migration and resettlement and address other potential social impacts such as health. The adoption and implementation of the priority technologies under water resources sector will increase productivity of water and enable the partial fulfillment of the objectives of maintaining and/or improving the health status of the populations, reduce saltwater intrusion into aquifers, and reduce flooding of water points under changing climate.

6.3 Results of the Technology Prioritization

The National Adaptation Consultant and stakeholders initially identified a long list of climate change adaptation technologies for the agriculture, coastal and water resources sectors which was reduced to a smaller number high priority adaptation technologies in each sector. The National Adaptation Consultant and stakeholders developed and used technology factsheets in selecting the technologies for further analysis and prioritisation using Multi-Criteria Analysis (MCA). Applications of defined criteria, units and weights to the identified adaptation technology options resulted to the prioritized ranking of the adaptation technologies for each sector as show in Table 14 below.

For the agriculture sector, Conservation Agriculture (96) was the highest ranked adaptation technology followed by Tidal Irrigation (78) and Aquaculture (73). For the coastal resources sector, sustainable sand management was the highest ranked adaptation technology option followed by breakwater systems and Groyne systems. Under the water resources sector, water Conservation was ranked the highest priority followed by relocation of water points from saline and flood areas

and aquifer recharge. These prioritized technologies will now be subjected to barrier analysis and translated to project areas under the next steps of the TNA process.

Table 14: Sectoral prioritized technologies under the TNA process

Agriculture Sector			Coastal Resources Sector			Water Resources Sector		
Rank	Option	Score	Rank	Option	Score	Rank	Option	Score
1	Conservation Agriculture	96.0	1	Sustainable Sand Management	69.3	1	Water Conservation	77.5
2	Tidal Irrigation	77.6	2	Breakwater Systems	68.1	2	Relocation of Water Points	53.3
3	Aquaculture	73.0	3	Groyne Systems	64.4	3	Aquifer Recharge	28.3

6.4 Recommendations

The process of development of Technology Needs Assessment is progressively becoming simpler with the availability of simplified methods and tools and the capacity building support provided by UDP and network partners. There are still major constraints and gaps in the availability of data and information that are required for development of Factsheets and the running of the MCA spreadsheet. Most of the constraints relate to lack of national data and information on the investment cost and the operation and maintenance of some of the new technologies that the Working Group recommended for adoption and utilization. The data on investment costs on some of the coastal zone management technologies are borrowed from the developed world and it is difficult to translate those costs to local conditions in The Gambia.

It is recommended that efforts are made to support countries to extrapolate regional and global data to the national circumstances.

REFERENCES

1. Brown, S., Kebede, A. S., and Nicholls, R. J., 2011. Sea Level Rise and Impacts in Africa, 2000-2100. School of Civil Engineering and the Environment, University of Southampton. 215pp.
2. Carlos M. Gómez, Dennis Colentine, Gonzalo Delacámara, Pierre Strosser, Ayis Iacovides, Gerda Kinell, Tore Söderqvist, Gábor Ungvári, and Benoît Fribourg-Blanc, 2013: Concept Note on Natural Water Retention Measures (NWRM) and the WFD and other daughter Directives Disambiguation, issues and open questions
3. Dökmen, F. (2006) Planning of Regional Strategy Development for Salinity in Agricultural Water Management, International Soil Meeting (ISM) on "Soil Sustaining Life on Earth, Managing Soil and Technology, Proceeding Book, Şanlıurfa, Turkey, p:662-664
4. Dökmen, F. and C. Kurtuluş. (2008a) Usability of Drilled Wells as Irrigation Wells, Journal of Food, Agriculture & Environment, Vol. 6 (2), p: 438-441.

5. Dökmen, F. and C. Kurtuluş. (2008b) Movement and Flow Velocity of Groundwater in Wells, Journal of Food, Agriculture & Environment, Vol. 6 (3&4), p: 470-472 .
6. Dökmen, F. and C. Kurtuluş. (2009) Temporal Variation of Nitrate, Chlorine and pH Values in Surface Waters, Journal of Food, Agriculture & Environment, Vol.7 (2), p: 689-69 .
7. GOTG (2011). Department of Parks and Wildlife Management 2001, The Gambia Wildlife and Biodiversity Policy;
8. GOTG (2014). The Fifth (5th) National Report to the Convention of Biological Diversity © May, 2014. Wildlife Management Abuko Headquarters Abuko, The Gambia. wildlife@gamnet.gm;
9. GoTG/AfDB, 2011: Rural Water Supply and Sanitation Project, Project Appraisal Report.
10. GoTG/GEF/UNDP, 2012: Climate Change Adaptation Project document on Enhancing Resilience of Vulnerable Coastal Areas and Communities to Climate Change
11. GOTG/MoECCFWW, 2016: The National Climate Change Policy of The Gambia;
12. GOTG/MoECCFWW, 2016: The National Climate Change Policy of The Gambia
13. GOTG-NCC, 2013: Second National Communications of The Gambia to the UNFCCC;
14. Government of Sudan, 2013: Technology Needs Assessment for Climate Change Adaptation – Sudan; accessed from <http://tech-action.org/>.
15. Jarju, Pa. Ousman, (2009)
16. MoA, 2009: Agriculture and Natural Resources (ANR) Policy (2009 – 2015);
17. MoE/URC/GEF, (2012). Lebanon Technology Needs Assessment report for Climate Change. Beirut, Lebanon.
18. MoHSW, 2011: The National Health Policy, “HEALTH IS WEALTH” 2012 – 2020: “Acceleration of Quality Health Services and Universal Coverage”;
19. MoWA, 2009: The Gambia National Gender Policy 2010- 2020;
20. Ousman Dainaneh Jarjusey, 2011: An assessment of investments and financial flows to address climate change in the Gambian water sector
21. PMO, 2007: Public Service Reform Sector Strategy Paper, 2007-2011;
22. SNH, 2011: A guide to managing coastal erosion in beach/dune systems; Summary 11: NEARSHORE BREAKWATERS http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.11.shtml
23. SNH, 2011: *Summary 12: GROYNES* - A guide to managing coastal erosion in beach/dune systems: www.snh.org.uk/publications/on-line/.../erosion/appendix_1.12.shtml
24. The World Bank, 2015: THE GAMBIA: Policies to Foster Growth; Volume II, Macroeconomy, Finance, Trade and Energy; May 19, 2015; 59pp. http://www.wds.worldbank.org/external/default/WDSPContentServer/WDSP/IB/2015/07/27/090224b08302a19a/1_0/Rendered/PDF/Macroeconomy00finance00trade0and0energy.pdf;
25. Yaqoob D/O M., S.B, and F. Dökmen. (2005) WasteWater Use in Agriculture and Effects of Salinity, International Conference, Biosaline Agriculture & High Salinity Tolerance, Proceeding of Biosaline Agriculture & Salinity, Muğla, Turkey, p: 103-106.

Annex I: Technology Factsheets for selected technologies

The following Technology Fact Sheets have been prepared by the Adaptation Consultant, shared with and reviewed by the sectoral stakeholders and finalized by the Consultant before being included in this Report.

1: Technology Factsheets from Agriculture

Name of Technology	Conservation Agriculture
Sector	Agriculture and Food Security
Sub-Sector	Agriculture
Introduction	Conservation agriculture is an agriculture system that aims at soil and water conservation, nutrient improvement and enhanced production. Conservative agriculture technologies are based on the principles of (a) minimal soil disturbance (zero-tillage), (b) maintenance of good soil cover (cover crops, residues and mulches), and (c) appropriate crop rotation or crop association depending on the availability of land. Consequently soil organic matter is conserved, water retention is increased, erosion and pollution are reduced, and the productivity of agricultural systems is increased even during the prevalence of drier climate phenomena such as droughts. Therefore, food security is assured during hungry periods especially in arid and semi-arid climatic conditions familiar to The Gambia.
Technology characteristics	Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible –the plant seed is sown directly into the seed bed. Zero tillage aims at making better use of agricultural resources through the integrated management of soil, water and biological inputs. Zero Tillage improves the soil, increases production and decreases the cost of production. It consists of improved agricultural packages including (a) crop residue from previous crop and crop rotation; (b) application of herbicide for control of emerging and non emerging weeds (pre-post emergence herbicides); (c) planting in rows and application of fertilizer in one operation by a special planter; and (d) starting agricultural operations after the soil has received 110 mm of rainfall. The Conservation Agriculture (CA) approach is recommended as a climate-resilient agricultural technique because conservation of soil organic matter increases the fertility and water-holding capacity of soils. This simple and cost-effective approach to increasing the climate resilience of agriculture is particularly well suited to low-input rain-fed agricultural systems such as those in The Gambia. The CA approach is compatible with the use of green manures i.e. the use of plant material to increase soil fertility. Intercropping involves planting two or more crops in close association, often focusing on nitrogen-fixing species. This approach can increase the climate-resilience of agriculture by diversifying the risk of monoculture farming, as well as by increasing soil fertility through planting of nitrogen-fixing crops.
Costs, including cost to implement adaptation options	Conservative Agriculture is less expensive in terms of capital cost (for machinery), in labor and energy than conventional agriculture. Costs associated with establishment of one production unit using zero tillage equipment (tractor, 90HP+planter+ sprayer) is 31,600 USD; In field crops, the cost of implementing the technology is reduced to the cost of the seeder or planter (2000\$). Cost of cultivating of one hectare by traditional method = 40 USD Cost of cultivation of one hectare by zero tillage method = 54 USD The production of one hectare using traditional system is 700kgs (7 sacks where 1 sack of crop = 100kg). The production of one hectare by zero tillage is 2,300kgs (23 sacks where 1 sack of crop = 100kg).
Additional cost to implement adaptation technology compared to "business as usual"	When compared to business as usual, there is no additional cost rather than a reduction by 350\$/ha at least (cost of land preparation). Examples of typical long term cost (i.e. 10, 30, or 50 years) without adaptation • Olives: annual plowing will cost 650\$/ha • Cereals (cost of production of a monoculture with till): 1200\$/ha Examples of typical long term cost (i.e. 10, 30, or 50 years) with adaptation • Olive: first year: 160\$/ha (green cover seeds and herbicide), then 30\$/ha starting the second year. • Cereals: (barley-vetch rotation with not till): 800\$/ha
Operation and maintenance:	Application of conservative agriculture technologies requires the use of specific seed machinery for seeding and sufficient large areas to adopt crop rotation (namely for cereals and legumes). To maintain soil fertility agriculture residues should not be removed. Training is required for technicians and farmers.
Potential development impacts, benefits	Zero tillage improves the productivity in rain-fed and irrigated farming systems. A fundamental criterion related to coverage is that annual rainfall must exceed 600mm. Thus, the targeted area for transfer and application of the zero tillage system is geographically large for The Gambia as rainfall is everywhere equal to or greater than 600mm. Application of conservative agriculture technologies shows that the cost of production is maintained as the inputs do not augment because soil fertility and water content are preserved. The major saving will be in terms of costs for tillage and land preparation for plantation. Production is sustained with minimal annual variation.
Economic	Adoption of conservative agriculture as an adaptation technology will enhance the attainment of farmers' needs as well as the development priorities of the country, particularly food security and poverty alleviation. There will be new job opportunities, increase of farmers' incomes, increased food production and encouragement of private sector investments in production of agricultural crops. An overall yield stability,

	a reduction in cost of production, and increases in farmer's income are realized. Revenue is increases of about 760\$/ha for cereal have been registered.
Social	The social benefits of zero tillage include improvement of living standards, upgrading the livelihood skills of farmers and enhancing their resilience to climatic and external economic shocks. Health status of communities will improve.
Environmental	Soil is preserved from the impact of climatic adverse (wind, rain, solar radiation) and evaporation is reduced, which increases soil water content and soil organic matter. Preservation of soil due to zero tillage reduces greenhouse gas emissions. Water retention and slowed surface runoff increases chances of the maintenance of soil cover, enhanced biodiversity in the soil, reduced desertification and resilience to floods.
Status	Zero tillage, a component of Conservative Agriculture, was applied in The Gambia on a relatively small scale in the 1980s and 1990s. However, due to increased human and animal population, reduction in productivity due to negative impacts of climate variability which is now compounded by climate change, the need to grow and produce more food in a shorter period arose. Agricultural mechanization was introduced which has negative impacts on the shallow and poor soils of The Gambia. Productivity continues to decline and there is need to go back to conservative agriculture.
Barriers	Opportunities include: • Potential reversal of declining unit area productivity through investment in zero tillage in the rain fed areas. • Application of Zero Tillage minimizes weeds and improves soil structure over long periods, leading to a decrease in the cost of production. • Adapting conservation agriculture to some crops may require specific machinery for seeding. • Conservation agriculture is suitable for arid and semi arid regions, to areas with soils suffering from low organic matter content and for areas prone to desertification Barriers include: • The application cost of zero tillage is high. • Conservation agriculture should be avoided in soils with high clay content, in humid areas with shallow water table, in saline soils and for crops with no residues left. • Small holders are unable to apply economically viable crop rotations, and unable to access to machinery.
Acceptability to local stakeholders	Heavy machinery and intensive applications of artificial fertilizers are not suitable for the soil conditions of The Gambia. Hence, conservation agriculture is acceptable to farmers and agriculturalists alike.
Endorsement by experts	Conservation agriculture is widely acknowledged, endorsed and promoted by experts and extension agents of The Gambia.
Timeframe	Conservation agriculture needs medium and long-term applications for sustainable outcomes.
Institutional and organizational requirements and capacity development	Institutional capacity development and maintenance are prerequisite activities to adopt the technology. Training and skills development of agriculturalists, farmers, private and business sector entities and other stakeholders in the adoption and application of technologies of zero tillage (planting, spraying and application of fertilizer) are paramount. For wide acceptance and applications of the technologies, more research and trials should be conducted in different administrative regions and agriculture zones of The Gambia.
Adequacy for current climate	Conservation agriculture is valid and adequate under current climate variability and change in The Gambia because of its semi-arid conditions and can have a role in reducing GHG emissions.
Size of beneficiaries group	Conservation agriculture can be adopted by all farmers in The Gambia.
Market potential	Products of conservation agriculture are more environmental friendly and with lesser pesticide residues. They, therefore have higher competitive potential on the market.

Title:	Surface/Tidal Irrigation System
Sector	Agriculture
Sub-Sector	Rice Culture
Technology Characteristics	
Introduction	In surface irrigation systems, water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. In The Gambia it is often called Tidal/flood irrigation when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land in The Gambia. Where water levels from the irrigation source permit, the flow is controlled by dikes, usually plugged by soil. This is often seen in terraced rice fields (rice paddies), where the method is used to flood or control the level of water in each distinct field. The Gambia River rises in Guinea and passes through Senegal before finally entering The Gambia for an approximately 500 km journey to the sea. The flow in the river is highly seasonal. The maximum flow occurs at the end of the rainy season in late September or October with a flow of about 1500 m³/s. The minimum dry season flow is less than 4.5 m³/s. Both measurements were taken at Gouloumbo in Senegal. Due to the large variation in river flow and the flat nature of the country's terrain, the Gambia River is tidal, and thus saline, for much of its length. The position of the interface between the freshwater and saltwater varies with river flow. During the low flow period, the freshwater-saltwater interface, defined as the point at which the salinity is 10 ppt, is 250 km from the sea. Under high flow conditions, this interface is located 150 km from the sea. Due to the perpetually saline conditions which exist in the Gambia River and its tributaries for 150 km from its mouth, where the population centres and tourism facilities are located, surface water is rarely used as a source of potable water in The Gambia. The potable water demand for urban areas, tourism, industry, and irrigation and livestock watering comes from groundwater sources.

	Groundwater is available in all parts of The Gambia. The country is located on one of the major sedimentary basins in Africa often referred to as the Mauritania/Senegal Basin. It is characterized by two main aquifer systems with water table depths varying from 10 m to 450 m.
Technology characteristics/Highlights⁴	This technology is intended to supplement rain fed agriculture. The availability of tidal water at high tide was used as source of irrigation water supply. Due to the use of this technology, a double cropping of rice is achieved annually in a country with seven months of dry season. The land along the Gambia River is relatively flat, and, since the river is tidal all through its length in The Gambia, tidal irrigation schemes become feasible. Tide heights vary from 3.5 m at the mouth of the river to 0.9 m at Basang, 310 km upstream. Special intake structures were constructed with gates which, when opened at high tide, allowed tidal waters to enter irrigation channels leading to the farms. During high tide, the gates were opened from 3 to 24 hours, depending on the size of the area to be irrigated. In the two rice growing areas, at Jahally and Pacharr, tidal and pump irrigation are coordinated. Tidal heights of 1.3 and 1.0 exist in the Gambia River at Jahally and Pucharr, respectively (Figure 45). Tidal water is utilized to irrigate low lands nearer the banks of the river while water is pumped from the river to irrigate large areas of land at higher elevations. The project began operations in 1983 and 1984 at Jahally and Pacharr, respectively.
Institutional and Organization requirements	The Irrigation and Agricultural Engineering Services of the Department of Agriculture are responsible for management of Tidal irrigation in The Gambia. Due to frequent staff attrition human capacity building will be needed for the expansion and management of irrigate areas Additional Farmers and Farmer Associations will be recruited and capacitated.
Operation and maintenance	Trained local staff must be available to perform the farming operations and management. Additional manpower needed to implement this technology include: (a) one power tiller operator for each 15 ha cultivated per month; (b) two tractor operators; and, (c) two experienced mechanics. There should be about 20% local community control or management.
Endorsement by experts	The technology is appropriate in areas where there is a river with a relatively flat basin and high tide intrusion. Arable land must be available near the banks of the river. The rainfall in the area must be sufficient to encourage constant and high river flows. The technology is also good for use in areas with fairly large rivers and sufficient rainfall to keep the water level high. The rivers must also be tidal.
Adequacy for current climate	Tidal irrigation is adequate under current climate for about half the length of the river. This may change under projected climate change due the upstream extension of the saline front.
Scale/size of beneficiary group	Tidal irrigation is applicable in the eastern half of the length of the River Gambia where many of the stakeholders are engaged in rice cultivation.
Disadvantages and disadvantages	This technology is good because once the intake structures and irrigation channels are constructed the operation is relatively cost free. Maintenance work on the irrigation channels and clearing of weeds and brush from the channels and irrigated area can be done by the local farmers. However, difficulty in the availability of spare parts locally is a disadvantage.
Capital Costs	
Cost to implement adaptation technology	Annual cost may be estimated at \$40/ha and operation and maintenance costs are \$220/ha/yr. With a resultant yield per hectare of 9 tons/yr, translates to incurring an annual cost per unit of output of \$70/ton.
Development Impacts, direct and indirect benefits	
Direct benefits	Rice farmers are engaged in cultivation and generate income throughout the year.
Indirect benefits	
<i>Reduction of vulnerability to climate change impacts</i>	According to the Second National Communication of The Gambia, there is less impacts of climate change on irrigated rice as water and temperature are currently not limiting factors.
<i>Economic benefits: employment, growth and investment</i>	Stakeholders are able to sell their products and generate income. Most of the employees in the cultivation of the rice fields are citizens of the region.
<i>Social benefits: Income</i>	Stakeholders own most of the rice fields and are involved in rice cultivation. The rice produced is used for consumption and as cash crop. Thus, socially the technology is found viable and helps the farmers to have enough food and cash for other social benefits such as for health and education purposes.
<i>Environmental benefits:</i>	The breeding of mosquitoes and snails is enhanced by water ponding on the farms, which could lead to public health concerns if control measures are not imposed.
Local context	
Opportunities and Barriers	The technology is appropriate in Gambia because the river basin is relatively flat with high tide intrusion during the rainy season. Both banks of the River provide adequate arable land in the freshwater zone of the river. The rainfall in the area is sufficient to encourage constant and high river flows during the wet season.
Market potential	Farmers in all the settlements close the flat lands of the freshwater zone of the Central River Region can adopt the tidal irrigation technology. All that is required is the construction of canals through which the tide flows into the crop fields and the construction of sluice gates that will be close when the tide withdraws keeping the water in the fields. There are potentials for the business and private sector entities to be involved in the manufacture and/or importation of spare parts for the constriction and maintenance of the canals and the gates.
Status	The tidal irrigation technology has been successfully practiced in the upper reaches of the River Gambia for many years and is a good for paddy rice cultivation in the Central River Region of the country. Using tidal irrigation, double cropping of 167 ha and 850 ha was achieved annually at Jahally and Pacharr.
Timeframe	The technology is applicable in the CRR around Kuntaur and Sapu throughout the year.
Acceptability to local stakeholders	No cultural inhibitions have been experienced. This technology provides for viable commercial farming in a poor rural area.
Images of Tidal Irrigation	

⁴ <http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8a/gambia.asp>



Title:	Aquaculture and Fish Farming
Sector	Fisheries
Sub-Sector	Inland/Artisanal Fisheries
Technology Characteristics	
Introduction	Aquaculture is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants that may entail stocking, feeding and providing protection from predators. Aquaculture involves cultivating freshwater and saltwater populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish. Mariculture refers to aquaculture practised in marine environments. Particular kinds of aquaculture include fish farming, shrimp farming, oyster farming, algaculture (such as seaweed farming), and the cultivation of ornamental fish. The farming of fish is the most common form of aquaculture. It involves raising fish commercially in tanks, ponds or ocean enclosures, usually for food. Fish species raised by fish farms include salmon, tilapia and catfish.
Technology characteristics/Highlights	The freshwater aquaculture systems used include pond aquaculture, rice-fish culture (either rice and fish together or rice followed by fish) on seasonal farmland, cage culture in rivers and lakes, pen culture in closed and open water bodies, and fish culture in such commonly held perennial water bodies as oxbow lakes. Aquaculture systems generally use free water sources, but some receive commercial irrigation or hire irrigation equipment. Pond fish culture is practiced in a closed water body and is a low-input activity for household consumption. Pond can be formed out of backyard areas excavated initially to acquire soil for construction.

	Ponds can also be constructed and connected to other water bodies during the rainy season, receiving runoff and becoming home to indigenous fish, which people catch during and after the rainy season. Fish farmers adopt a variety of culture systems to suit the diversity of ponds. Rice-fish culture is common in open water bodies, and carp poly-culture and tilapia mixed culture are common. Rice-fish culture follows two patterns: • Pond or ditch beside rice land, operated in small scale and by small farmers, is usually dominated by such exotic fish as tilapia and catfish, with lesser numbers of carp. The major difficulties of this culture system are poor water quality and vulnerability to seasonal flooding, which allows fish to swim away, leaving farmers with serious economic losses⁵. • Fish culture in seasonally flooded rice land involves (a) the concurrent culture of deepwater rice with stocked fish during the flood season and dry-season rice in shallow flooded areas; and (b) the alternating culture, with dry season rice followed by stocked fish in a closed area during the flood season. Fish culture in communally held water bodies is fish culture in water bodies that include rivers, oxbow lakes, canals and perennial lowland water bodies. Aquaculture operators in these types of water bodies are often fisher cooperatives, community groups and farmer groups. Cage culture involves the use of net boxes in open water bodies and other perennial water bodies, especially in freshwater rivers. Pen culture involves the use of pens made of bamboo and netting of polyethylene, nylon or plastic and usually placed in such semi-closed water bodies as irrigation and drainage canals but sometimes in large, open water bodies. Traditionally, fish feed mainly on naturally occurring plankton, though farmers sometimes apply low-protein natural materials as supplemental feed. Carp and tilapia are suitable for this type of aquaculture. Hatchery culture in freshwater environments chooses carp and catfish. In coastal saline environments most hatcheries choose shrimp. Nursery culture produces carp for freshwater aquaculture. The use of artificial illumination can increase growth rates and therefore reduce the length of the production cycle, as fish can achieve the 3kg market minimum weight six weeks earlier than in unlit cages⁶.
Institutional and Organization requirements	The development of the aquaculture sector depends on the policy and institutional environment, which spans a wide range of laws, regulations, administrative directives, institutions, services, infrastructure support and incentives. Aquaculture development in The Gambia is guided by principles laid out in the Fisheries Policy, the Fisheries Strategic Development Framework and the Program for Accelerated Growth and Employment (PAGE). Other relevant policies are National Water Policy, Agriculture and Natural Resources Policy and the Wildlife and Biodiversity Policy.
Operation and maintenance	In addition to fixed capital costs, there are variable costs for operations and maintenance of aquaculture systems. The variable costs include farm maintenance, feed, seed, fuel/energy, farm management (salary and wages), certification charges, pond preparation charges, inputs (lime, organic fertilizers) and harvesting expenses. The farm maintenance costs are as follows: • US\$770 for Modified Traditional Organic Shrimp Farm of about 20ha; • US\$14,610 for Semi-intensive Organic Shrimp Farm of about 20ha; and • US\$3,000 for Extensive Freshwater Prawn and Freshwater Fish farm of about 20ha each.
Endorsement by experts	Aquaculture Unit exists under the Department of Fisheries and is staff with some experts. These experts have endorsed aquaculture as a viable climate change adaptation technology. The extension agents and the fisher folks engaged in aquaculture also endorse the technology.
Adequacy for current climate	Aquaculture has been practiced in The Gambia for more than 15 years though at a small scale. The current climate is adequate for the technology and the projected climate change will also be adequate for the technology.
Scale/size of beneficiary group	The Republic of The Gambia consists of both banks of the River Gambia. The country is the valley of the River Gambia and this is therefore a relatively low elevation country. The River Gambia is tidal, flows in both directions and has both freshwater and saltwater zones. Aquaculture can be practiced on both banks of the River Gambia
Disadvantages	Installation of aquaculture farms and infrastructure can cause environmental damage, conflict over resource usage, creation of a resource sink, disruption of social structure, loss of traditional occupations, and reduction in fish price due to increase in supply.
Capital Costs	
Cost to implement adaptation technology	• The fixed cost of a Modified Traditional Organic Shrimp Farm of about 20ha is estimated as US\$30,700; • The fixed cost of semi-intensive culture method on a 20ha farm is estimated at US\$338,800; and • The fixed cost of Freshwater Prawn and Freshwater Fish farm of about 20ha is estimated at US\$14,500.
Development Impacts, direct and indirect benefits	
Direct benefits	
Reduction of vulnerability to climate change impacts	The development of aquaculture helps to increase fish supplies and protein, improve the supply of fishery products and enhances export earnings. Vulnerability to climate change induced food insecurity is reduced due to increased supply of fish food and protein. Increased income from sale and exports of fish products means that farmers and fisher folk can purchase food products other than fish. Better nourishment also translates to lower susceptibility to diseases and more hours to work.
Indirect benefits	

⁵Dey MM, Bose ML, Alam MF. 2008. Recommendation Domains for Pond Aquaculture. Country Case Study: Development and Status of Freshwater Aquaculture in Bangladesh. WorldFish Center Studies and Reviews No. 1872. The WorldFish Center, Penang, Malaysia. 73 p.

⁶ INFOFISH, 2011: Feasibility Study on Organic Aquaculture: Shrimp, Freshwater Prawn and Freshwater Finfish.

Economic benefits: employment, growth and investment	Aquaculture products fill a distinctive niche in the market, that of the high value, high quality seafood product (e.g. smoked salmon, fresh oysters). These products will complement, rather compete with, the supply from wild fisheries in the marketplace. Decrease in the price of some species and undoubtedly an increase in consumer surplus for them can be observed. The creation of new products is a possibility. The aquaculture industry has developed a good reputation for a well-graded uniform product with good opportunities for product differentiation based on a steady supply of quality raw material. The returns to aquaculture are higher than alternatives and these returns might increase over time as the international demand for products such as shrimp increases, and the fish farmers have become increasingly familiar with the activity and therefore are better able to take advantage of their engagement in it.
Social benefits: Income	Aquaculture production from isolated regions (away from population centres) ensures that consumers will receive a high-quality product with minimal health risks. The creation of employment opportunities in depressed rural areas is often cited as one of the most important reasons why local and national governments have been willing to encourage the development of aquaculture. Aquaculture can be a focus for rural development and stabilization, and a source of employment opportunities in depressed rural economies.
Environmental benefits:	In areas where aquaculture holds high promise of export earnings farmers have always taken to farming fish and other aquatic species in large scales and the people become more prosperous over time. They then become less dependent on the natural resources and environmental depleting activities such as illegal logging of forests. These will lead to avoidance of water quality degradation and associated biodiversity losses and the avoidance of the use of chemicals for disease management in farms. Other lost income associated with a decline in water quality, such as tourism and recreational fishing are also avoided.
Local context	
Opportunities and Barriers	Those businesses that are financially strong are more likely to survive in the face of adverse changes in the environment and by supporting the strongest businesses; social as well as economic objectives will be achieved. Barriers include (a) a continuing fall in market price, associated with oversupply problem may ultimately threaten the viability of the industry itself; (b) the adoption of new technologies and mechanization may lead to a reduction in the size of the workforce; (c) communities that become heavily dependent on aquaculture and switched away from more traditional occupations, may be increasingly vulnerable to external financial strains and 'boom and bust' economics; (d) aquaculture as a focus for rural development under the wrong circumstances is capable of producing as unsatisfactory an outcome as any other activity; (e) environmental restrictions and disease may constrain developments for some species; and (f) given the high risk associated with aquaculture activities, any inclusion of explicitly short-term social objectives (employment, business type, etc.) as a trade-off against viability and profitability leads to a danger that enterprises will be selected with a poor chance of long term survival.
Market potential	Procurement, replacement and maintenance of aquaculture equipment and infrastructure, feed, seed, fuel/energy, and inputs (lime, organic fertilizers) will encourage business and private sector entities to participate in the procurement and maintenance processes. The market potential is huge as expansion of the application of the technology in about three-quarters of the country is viable and will be exploited.
Status	Currently, aquaculture is applied in less than one-third of the country. There is potential to expand to technology to two-thirds of the country.
Timeframe	Expansion of aquaculture from the current area of less than one-third to two-thirds of the country will require about ten years of gradual implementation.
Acceptability to local stakeholders	Local stakeholders in Kombo East District of West Coast Region and the Fulladou Districts of the Central River Region have experience in implementing aquaculture and have embraced and accepted the technology.
	



Concrete grow-out tanks for shrimp (LEFT) and atypical small-scale tilapia grow-out system (RIGHT)

2: Factsheets for Coastal Resources Technologies

Title:	Sustainable Sand Management
Sector	Coastal Zone
Sub-Sector	Shoreline
Technology Characteristics	
Introduction	Sustainable sand management is a combination of structural measures and technologies together with nonstructural alternatives. Typical structural combination is beach stabilization structures (Groins or detached breakwaters) and beach nourishment. Beach fill on a regular basis must also supplement this combination. Together, their life-cycle costs and environmental impact may be less than if selectively and separately implemented. The combination mitigates downdrift impacts and/or increases the fill life of the nourished beach. Construction of the beach stabilization structures without fill is likely to damage adjacent beaches. Sustainable sand management reduces downdrift impacts by slowing the loss of placed sand. Beach rebuilding is sustainable as sand is being moved from where it has been deposited, to where it has been eroded from.
Technology /Highlights	characteristics To control the amount of sand moving alongshore, it is good coastal engineering practice to combine beach nourishment with groin construction to permit sand to immediately begin to bypass the groin field. To minimize downdrift impacts, beach nourishment and groin construction should be concurrent. Construction of the first groin should be at the downdrift end of the project. Net drift will combine with the artificial beach nourishment to fill and stabilize the first compartment. The second groin is then constructed and the process is repeated. At the end of the sediment cell, a terminal groin can be used to anchor the beach and limit the movement of sand. Gradually working updrift, the groin field construction is completed. This process together with tapering the ends will help to minimize the impact to adjacent, downdrift beaches. Beach nourishment is the process of dumping or pumping sand from elsewhere onto an eroding shoreline to create a new beach or to widen the existing beach. It is a process by which sediment (usually sand) lost through long shore or erosion is replaced from sources outside of the eroding beach. A wider beach can reduce storm damage to coastal structures by dissipating energy across the surf zone, protecting upland structures and infrastructure from storm surges, tsunamis and unusually high tides.⁷ Beach nourishment is typically a repetitive process, since it does not remove the physical forces that cause erosion, but simply mitigates their effects. Sediment texture (grain size and sorting) is critical for success of beach nourishment. Sand fill must be compatible with native beach sand. In some cases, beaches have been nourished using finer or coarser sand than the original. Thermoluminescence monitoring reveals that storms can erode such beaches far more quickly than the natural beach.
Institutional and Organization requirements	The National Environment Agency; the Geology Department; Department of Physical Planning; the Department of Lands and Surveys; the Department of Technical Services under the Ministry of Works and Infrastructure; the Local Government Authorities of Banjul, Kanifing and Brikama; and the Tourism organizations (Department, Board and Hotel Association) are responsible for the management of the coastal resources relevant to pollution, land loss and damages. All these institutions have some level of expertise in implementation and management of coastal technologies and infrastructure. However, experience in the past ten years has shown that there are collaborative, cooperative and coordination shortcomings in their operations to effectively manage the coastal resources. The institutions also need enhanced institutional and human capacity which is currently inadequate. To implement the proposed technologies, these shortcomings must be seriously addressed and overcome. Institutions must exercise their mandates collaboratively and efficiently for effective management of the coastal resources.

⁷https://en.wikipedia.org/wiki/Beach_nourishment

Operation and maintenance	For the combined technologies to be effective and serve a longer lifetime, regular monitoring and maintenance of identified defects and damages must be conducted. Regular re-nourishment of the beach is required and must be effectively planned and implemented.
Endorsement by experts	Groynes have been implemented on the coastal zone of The Gambia since the 1950s. They have been found to be effective and have been endorsed by experts as one of the most successful in limiting loss of land due to erosion of the shoreline. Beach nourishment was implemented along sensitive areas of the coastal zone of The Gambia in 2003 and 2004. It is also endorsed by experts but because of the rate of loss of the placed sand, some experts have serious reservations on pumping sand on the beach without construction of accompanying shoreline stabilizations structures.
Adequacy for current climate	Seawalls, groynes, revetments and beach nourishments have all been individually tried on the coastal zone of The Gambia. All of them have served their purposes under current climate. However, they may not be adequate under the projected climate change.
Scale/size of beneficiary group	Sustainable sand management will be needed along the entire length of the coastal zone and the estuary of The Gambia. All the settlements and communities within 20Kms of the shoreline are beneficiaries.
Disadvantages	Advantages for the implementation of the sustainable sand management technologies include (a) Retention of the natural appearance of the beach, (b) the recreational beach is widened, and (c) structures behind the beach are protected as long as the added sand remains. There are disadvantages. Off shore dredging of sand and shingle increases erosion in other areas and affects ecosystems. The impacts of large storms on nourished beach calls for periodic beach replenishment which increasing costs depending on the source of the sand. The improper functional design, or construction without adding extra material, produces adverse environmental impacts by starving the supply of sand to downdrift beaches. The beach turns into a construction zone during nourishment and the process of nourishment may damage, destroy or otherwise hurt marine and beach life by burying it. The sand added to the beach is often different from the natural beach sand. It can be hard to find a perfect match.
Capital Costs	
Cost to implement adaptation technology	Taking the Miami Beach as an example, the capitalized annual cost is about \$4 million. Pumping material can be expensive (at least £1,250 per cubic metre) unless it is a by-product of channel dredging.
Development Impacts, direct and indirect benefits	
Direct benefits	
Reduction of vulnerability to climate change impacts	The coastal zone of The Gambia is regarded as one of the sixteen most vulnerable at the global level. Reducing sea level rise induced erosion of the coastal zone and estuary of The Gambia will help keep valuable land and property and will save the lives of communities and their livelihoods. About 92 square kilometers of land useful for agriculture, fisheries, biodiversity and forest products will be saved. Food and ecosystem security will be enhanced, thus reducing vulnerability of climate change.
Indirect benefits	
Economic benefits: employment, growth and investment	Waterfront property on the coastal zone of The Gambia is generally of greater value and generates higher property taxes. The Fisheries and Tourism sectors generate the greater volume of their contributions to the national GDP from activities on the coastal zone. Innumerable secondary (ripple effect) benefits result from the coastal, beach-related travel and tourism industry. The economic value of beaches in The Gambia is well known as Gambia Tourism is entirely dependent of the sun and the beaches.
Social benefits: Income	Communities, Fisher folk, farmers, tourism operators and other stakeholders earn high income when the beach and structures are saved, kept and maintained. They are able to recruit more staff whose earnings are well put into other social benefits such as education and health for their families and themselves.
Environmental benefits:	Sustainable sand management including beach nourishment has many positive environmental impacts that include bringing new material to sand starved beaches and expanding the beach habitat. Species that were lost due to reduced beach area and loss of ecosystems will return. A particular example is the restoration of beaches and habitats for turtles and migrant birds near Tanji and Brufut.
Local context	
Opportunities and Barriers	Combined adaptation technologies for sustainable sand management can provide protection to communities and properties against rising sea levels, storm surges, and coastal inundation. Low human and institutional capacities, inadequate coordination and insufficient regulations prevalent in the institutions that are key in the implementation of these sustainable sand management technologies present big barriers and must be removed. Inadequate financial resources are barriers and financial assistance for development partners will be necessary.
Market potential	Implementation of the combination of beach nourishment, groins and/or breakwaters will provide business entities and the private sector of The Gambia potentials to manufacture and/or import materials for the construction, operations and maintenance of the structures. Contractors will be employed to carry out the required works.
Status	Sea walls, groins, revetments and beach nourishments have all been implemented on the coast of The Gambia. Breakwaters have not been implemented and studies conducted under the GOTG/GEF/UNDP LDCF NAPA Coastal Zone project has pointed to the feasibility of applying the breakwater technology in the Senegambia and Kairaba Hotels area. Sustainable sand management that combines beach nourishment and groins, as has been tried at Cape Point area is proposed for upscaling to all other parts of the coastline.
Timeframe	Implementation of beach nourishment in combination with groins or breakwater systems for the entire length of the 70km coastline of The Gambia will take more than five years.
Acceptability to local stakeholders	Local communities especially fisher folks and farmers along sensitive areas on the Kombo Peninsular accept and appreciate efforts of the Government to restore eroded land at these sensitive areas. Hotels and tourism operators also conducted activities to safe their hotels and operations and therefore accept the sand management combination with groins or breakwaters.



An attempt to protect the Senegambia Beach Hotel against coastal erosion before beach nourishment of 2003 2004



Kololi Beach area in 2002 before the beach nourishment of 2003 and 2004



A 100-metre wide beach created after the beach nourishment of 2003 and 2004. No shoreline sand stabilization structures were added to keep the sand. What happened next? See pictures that follow



Kololi Beach Area in 2010 – 7 years after nourishment, The area is back to where it was before nourishment because there are no groins constructed to reduce the downdrift movement of the sand



Beach nourishment activities (ref.: https://en.wikipedia.org/wiki/Beach_nourishment+

Title:	Groyne system to control coastal erosion
Sector	Coastal Resources
Sub-Sector	Coastal Zone Management
Technology Characteristics	

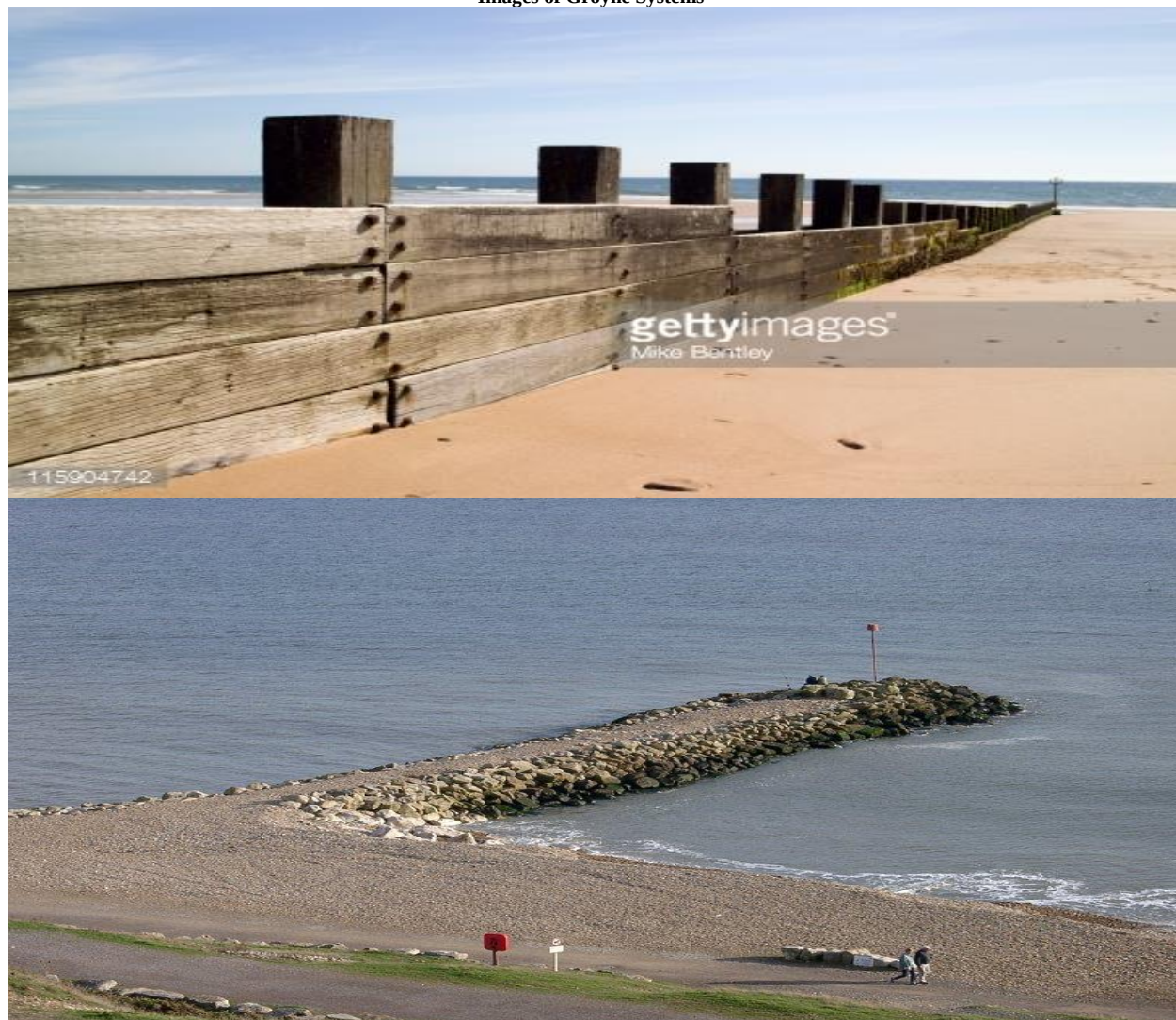
Introduction	Groynes are wooden structure but can also be made of concrete and/or rock barriers or walls perpendicular to the sea. Beach material builds up on the updrift side, where littoral drift is predominantly in one direction, creating a wider and a more plentiful beach, therefore enhancing the protection for the coast because the sand material filters and absorbs the wave energy. However, there is a corresponding loss of beach material on the downdrift side, requiring that another groyne to be built there. Groynes are extremely cost-effective coastal defense measures, requiring little maintenance, and are one of the most common coastal defense structures. Groynes are common in The Gambia and have done well in the past. Lack of wood for their construction has limited their use but this can be overcome with the use of concrete, which is relatively more expensive.
Technology characteristics/Highlights	Groynes are cross-shore structures designed to reduce long-shore transport on open beaches or to deflect near-shore currents within an estuary. On an open beach they are normally built as a series to influence a long section of shoreline that has been nourished or is managed by recycling. They trap beach material and cause the beach orientation to change relative to the dominant wave directions. Sand is carried in temporary suspension during higher energy wave or current conditions and will therefore tend to be carried over or around any cross-shore structures. They mainly influence bedload transport and are most effective on shingle or gravel beaches. Groynes can also be used successfully in estuaries to alter nearshore tidal flow patterns. In an estuary they may be single structures. Rock is often favoured as the construction material, but timber or gabions can be used for temporary structures of varying life expectancies (timber: 10-25 years, gabions: 1-5 years). Groynes are often used in combination with revetments to provide a high level of erosion protection. Groynes along a duned beach must have at least a short "T" section of revetment at their landward end to prevent outflanking during storm events. The revetment will be less obtrusive if it is normally buried by the fore-dunes. Beach recycling or nourishment is normally required to maximize the effectiveness of groynes. On their own, they will cause down-drift erosion as beach material is held within the groyne bays⁸.
Institutional and Organization requirements	Monitoring of the coastal environment is the responsibility of the Coastal Working Group at the National Environment Agency. Design, construction and management of coastal defense structures are the responsibilities of the Technical Services Department of the Ministry of Works and Infrastructure Development. At the municipality level, Mayoral offices of Banjul and Kanifing are involved in the decision making.
Operation and maintenance	The residual life of a groyne on a sand beach is approximately 20-25 years ⁹ . Maintenance equipment has become more specialized with time, and is worth about £25,000. Groynes which reach 25 years need to be dismantled and assessed. Groyne piles need to be replaced every 25 years, and planks every 15-20 years.
Endorsement by experts	Experts at the Ministry of Works and the municipalities have long endorsed groyne systems as they have saved the city of Banjul for more than 30 years. Lack of materials to replace broken timber made the systems to collapse. Use of rock and concrete will solve this problem.
Adequacy for current climate	Groynes are adequate for current climate and for the projected climate in The Gambia. Adequate supply and appropriate materials (timber or rock) are required.
Scale/size of beneficiary group	The Gambian shoreline is in a highly dynamic sandy coast and groynes can be installed all along the coast.
Advantages and Disadvantages	Rock groynes have the advantages of simple construction, long-term durability and ability to absorb some wave energy due to their semi-permeable nature. Wooden groynes are less durable and tend to reflect, rather than absorb energy. Gabions can be useful as temporary groynes but have a short life expectancy. They are good on exposed shorelines with a natural shingle upper beach. Can also be useful in estuaries to deflect flows. Unlimited structure life for rock groynes. Disadvantages include disruptions in natural processes and public access along upper beach; causing down-drift erosion as they starve beaches further down the coast of sediment which can result in coastal erosion; and the resultant down-drift erosion could destroy buildings or private land and lead plummeting of housing prices in the region making it difficult for affected homeowners to move out. They are also quite expensive.
Capital Costs	
Cost to implement adaptation technology	Cost of installation of groynes is moderate, but must include for recycling or nourishment. Hence the cost is in the range £10,000-£100,000 per structure, plus recycling. Construction costs are mainly dependent on structure dimensions, but can be heavily influenced by the availability of suitable rock (or other material), transport and the associated costs of recycling or nourishment. Rock structures can be assumed to have an unlimited life with respect to economic assessments.
Development Impacts, direct and indirect benefits	
Direct benefits	Groynes reduce dependency on regular recycling or nourishment, and therefore reduce future disturbance of the shoreline environment. Localized accumulations of beach material will encourage new dune growth. If constructed in conjunction with a revetment, recycling, fencing and transplanting will help to keep the revetment sections buried, thereby enhancing habitat regeneration. Groynes encourage upper beach stability and reduce maintenance commitment for recycling or nourishment.
Indirect benefits	
<i>Reduction of vulnerability to climate change impacts</i>	Coastal erosion is reduced as sediment is trapped by the groyne.
<i>Economic benefits: employment, growth and investment</i>	As groynes trap sediment from long-shore drift the beach builds up supports tourism, and creates a positive multiplier effect on the local economy (good for retail, catering and transport jobs).
<i>Social benefits: Income</i>	
<i>Environmental benefits:</i>	Timber used for groyne construction should be derived from sustainably managed forests. Fencing and transplanting should be undertaken to establish a new line of fore-dunes along the stabilized upper beach.

⁸ Summary 12: GROYNES - A guide to managing coastal erosion in beach/dune systems: www.snh.org.uk/publications/on-line/.../erosion/appendix_1.12.shtml

⁹ Minutes of the SCOPAC Timber Groyne Workshop 24th March 2010

	These dunes will enhance the coastal landscape, provide additional erosion protection and re-establish a natural succession of dune habitats from the shoreline to the backshore.
Local context	
Opportunities and Barriers	Groynes have a significant impact on the landscape and can create barriers to the recreational use of the upper beach. They often cause down-drift erosion unless there is a long term management commitment to beach recycling or nourishment. Down-drift erosion may well lead to pressure for further defense works. Timber groynes must be built from hardwood to endure the harsh shoreline environment. Much hardwood comes from tropical sources, making it both costly and potentially environmentally unacceptable. Timber groynes tend to reflect, rather than absorb, wave energy making them significantly less effective than rock on exposed coasts. They are also more likely to structural failure due to formation of scour channels around their seaward ends.
Market potential	The groyne systems in The Gambia have been constructed out of matured rhun palm trees with do well in saline conditions. There is acute shortage of these trees in The Gambia but there is abundant supply in neighbouring Senegal and Guinea Bissau. Business entities can take advantage of the market potentials. Concrete groynes also provide business entities with potential to procure concrete materials from the construction of the groynes.
Status	Both timber and rock groynes have performed very well in The Gambia. As a general rule, groynes should not be built on an open beach unless construction is accompanied by a commitment to regular recycling or nourishment. Without this commitment the groynes are likely to cause down-drift erosion as the upper beach becomes starved of sediment.
Timeframe	Because of salinity levels along the coast of The Gambia, rock and timber groynes stay longer before repairs are required. Beach recycling or nourishment is normally required to maximize the effectiveness of groynes.
Acceptability to local stakeholders	Coastal stakeholders have accepted groynes.

Images of Groyne Systems





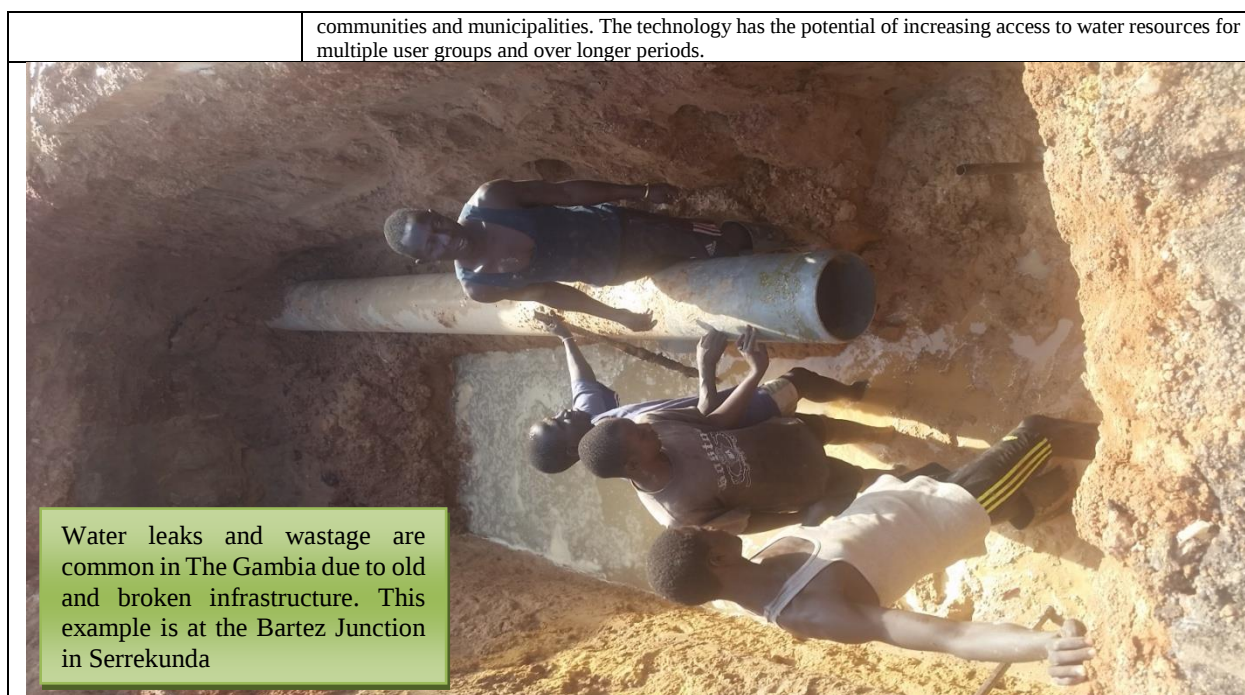
Title:	Breakwater coastal defense technology
Sector	Coastal Resources
Sub-Sector	Coastal Zone Management
Technology Characteristics	
Introduction	Enormous concrete blocks and natural boulders are sunk offshore to alter wave direction and to filter the energy of waves and tides. These are offshore breakwaters facilitating the breaking of the waves further offshore and therefore reduce their erosive power. This leads to wider beaches, which absorb the reduced wave energy, protecting infrastructure and property behind.
Technology characteristics/Highlights	Massive concrete blocks and natural boulders are sunk offshore to alter wave direction and to filter the energy of waves and tides. The waves break further offshore and therefore reduce their erosive power. This leads to wider beaches, which absorb the reduced wave energy, protecting cliff and settlements behind. The Dolos which was invented by a South African engineer in East London has replaced the use of enormous concrete blocks because the dolos is much more resistant to wave action and requires less concrete to produce a superior result. Breakwater is designed to dissipate the force of incoming waves by allowing water to flow around rather than against it, and to reduce displacement by allowing a random distribution of tetrapods to mutually interlock.
Institutional and Organization requirements	Monitoring of the coastal environment is the responsibility of the Coastal Working Group at the National Environment Agency. Design, construction and management of coastal defense structures are the responsibilities of the Technical Services Department of the Ministry of Works and Infrastructure Development. At the municipality level, Mayoral offices of Banjul and Kanifing are involved.
Operation and maintenance	Breakwater systems have a life span of 25 to 50 years. Given the natural forces to which breakwaters are constantly subjected, maintenance (and eventually replacement) is an ongoing requirement if they are to provide an effective long-term solution.
Endorsement by experts	Experts at the Ministry of Works, Ministry of Environment, Ministry of Tourism, the National Environment Agency, the municipalities and other stakeholder institutions endorsed the installation of breakwaters around the Senegambia coastal stretch under the GOTG/GEF/UNDP LDCF Coastal project.
Adequacy for current climate	Studies have indicated that the breakwater systems are adequate for current climate and for the projected climate in The Gambia if they are constructed to standard and with most appropriate materials.
Scale/size of beneficiary group	The coast is generally a high-energy, dynamic environment with spatial variations occurring over a wide range of temporal scales. Breakwater systems can be designed and constructed for all the coastal zone of The Gambia but being a sandy coast the systems need to be constructed to greater depths and thus becoming more expensive.
Disadvantages	The advantages of breakwater system include waves breaking further offshore so as to reduce erosive power and they also allow the build up of sand. Disadvantages include inadequacy to handle heavy storms and they are difficult to install.
Capital Costs	
Cost to implement adaptation technology	Typical cost estimate is about £1,900 - 2,000 per m. Water depth may increase the cost.
Adaptational: cost to implement adaptation technology compared to "business-as-usual"	Additional cost may be incurred due to increase in the depth as the coastal zone of the Gambia is sandy in nature.
Development Impacts, direct and indirect benefits	
Direct benefits	Reduces the incident wave energy and thus the erosive power of the waves. Produces accretion of sand on the beach.

Indirect benefits	
<i>Reduction of vulnerability to climate change impacts</i>	Reduces soil erosion, lost of beach and infrastructure
<i>Economic benefits: employment, growth and investment</i>	Economic activities and infrastructure are protected and continue to grow including employment. Tourism prospers
<i>Social benefits: Income</i>	Employment is generated and income generating activities are conducted providing stakeholders with financial means of meeting health needs and education for their children
<i>Environmental benefits:</i>	The breakwater systems can be used as habitat by many aquatic species. The installation of the system can also destroy existing habitats.
Local context	
Opportunities and Barriers	When constructed well and out of materials which can withstand the force of ongoing wave energy, breakwater systems can be a successful way to control coastal erosion by reducing the incident wave energy on shoreline.
Market potential	Business entities can be engaged in procurement of materials required in the construction and maintenance of breakwater systems.
Status	A feasibility study under the GOTG/GEF/UNDP LDCF NAPA project on the coastal zone has concluded on the viability of the technology in reduction of erosion on the shoreline.
Timeframe	Construction can be fast if all the required materials are available on site. Breakwater systems can survive 25 years or more with regular monitoring and maintenance.
Acceptability to local stakeholders	The installation of breakwater systems is acceptable to stakeholders as the structure protects their property and livelihoods from erosion and floods. However, the structure must be visible and be properly spaced to protect fishing boats during operations.
	
Images of Offshore Breakwater systems	

3: Technology Factsheets for Water Resources

Name of Technology	Water Conservation
Sector	Water Resources
Sub-Sector	Community Water Supply
Introduction	Improvement of freshwater availability can be achieved through reduction in water losses, decrease in water demand and effective management of water supply systems using Village Water Committees (VWCs). Water losses in community water supply systems can occur during storage, transmission, or delivery through evaporation, leakage (often due to aging infrastructure), or improper, illegal, or uncontrolled use. The losses are substantial, and they are likely to increase with rising temperatures.
Technology characteristics	Water loss reduction is a suitable approach in almost any environment, but especially in locations with impervious soils that are facing water shortages. It is also an important technology to consider in areas with aging water distribution infrastructure. Water losses can be reduced during distribution by implementing an active leak detection program; identifying illegal taps and connections; installing or calibrating water meters; reducing main breaks by rehabilitating and replacing water mains; and developing an “asset management” strategy for maintaining and improving existing infrastructure. Reducing water losses will increase water available for use and reduce abstraction from surface water and groundwater supplies. Improvement of freshwater availability technologies can be supplemented by several existing technologies and policy tools for reducing water demand. Demand for water can be reduced and the efficiency of water use by households and commercial entities increased with the help of new technologies (e.g., no- or low-flow toilets, low-flow showerheads, reformulated manufacturing techniques), as well as policies (e.g., water tariffs, reduction of non-revenue water, integrated water resources management).
Costs, including	
cost to implement adaptation options	A major source of water loss is aging infrastructure, which is costly to repair or replace. Leak detection and repair can also be costly, depending on the size of the system. Cost assessments should be made to evaluate the economic losses from leakages versus the resources required to reduce the water losses. Covering or lining storage facilities to reduce evaporation is most cost-effective for small facilities. Lining canals is efficient but expensive, although costs vary from concrete linings, the most expensive option, to colmation,

	the least expensive. In fact, this method is rarely used, despite the significant reduction in water losses that it can achieve, because of the expense involved. While water is typically undervalued, climate change will affect the availability of water, thereby increasing its value and the economic benefit of strategies for reducing water losses. The market for water loss reduction depends on the costs of water and the distribution of incentives for addressing losses.
cost of not modifying the project	Not modifying or adopting improvement of freshwater availability would mean higher cost of monitoring and maintenance of infrastructure as climate changes.
Potential financing and markets:	Where water loss reduction offers financial benefits to the owners of water storage and distribution infrastructure. Significant market potential exists for investment in materials and infrastructure for reducing water losses. Business entities can forge partnerships with the national water utility (NAWEC) for financing and maintaining some of the components of the water distribution systems such as leak reductions and through the partnerships the business entities receive a percentage of the profits and savings from the water utility.
Potential development impacts, benefits	Reducing water losses can produce a number of co-benefits. In some circumstances there may be indirect environmental impact from the construction associated with building or repair work.
Economic	Reducing the amount of water lost in transmission means that less water has to be pumped to deliver the desired volumes to the user locations. Energy will be saved in the process. The technology supports employment at the community through ensuring availability of water for off season farming activities. The technology requires low investment for capacity building of Village Water Committees. There will be reduced public and private expenditures on climate related disaster management through its support to building community resilience.
Social	Minimizing leaks in water distribution systems means that less pathogens and other contaminants can enter potable water supplies. Adequate water pressure is also maintained at water hydrants used by Fire Fighting Services to provide protection against fires. Reducing large-scale leaks will keep water tables from rising and causing damage to building foundations and other critical infrastructure, or creating seepage areas where mosquitoes and other disease-spreading pests may breed. Using Village Water Committees for provision of effective management of the water supply systems provides extra income for farmers' groups through increasing water availability for production and through improved management of water resources that supports improvement in water quality. The savings accrued are used to reduce health risks within communities. The VWCs also develop market cooperatives that ensure effective marketing of members' produce and create opportunity for increased group and individual earnings at group and community level.
Environmental	Minimizing water losses means less pumping, reduced energy use and reduced GHG emissions. Reducing residential and commercial water use can ease pressure on ecosystems that provide surface water and create a number of other environmental co-benefits.
Status	Expansion and modernizing community water supply systems are well advanced in The Gambia. However, management of the water supply systems by Village Water Committees needs improvement by building the capacities of members in financial management, including planning. Suppliers of materials and the mechanics responsible to the monitoring and maintenance of the infrastructure also need further training and better resources (for mobility) for effectiveness in their operations.
Barriers	Aging water distribution infrastructure, the limited resources for O&M, and limited control against illegal connections call for priority attention. Among the biggest barriers to water loss reduction is the paucity of research into losses due to aging water distribution infrastructure, unauthorized access and illegal connections, cost-benefit analyses of repairs, and proper building or repair technologies. It is important to maintain accurate utility and customer meter data. Split incentives, in which the party that finances the mitigation measures does not benefit from the reduced losses can serve as disincentives and hinder the implementation of the measures. A weak Village Water Committee poses the risk of poor management performance. Undue political influences and bias to a particular political party also limits the effectiveness of the Village Water Committee members in the execution of its duties.
Acceptability to local stakeholders and Feasibility of implementation	Most of the community water supply in The Gambia comes from boreholes with piping to tap heads. Strategies for limiting water losses in distribution networks requires improving O&M as well as replacing aging infrastructure. Recently, metering has been introduced for effective monitoring of usage and detection of wastage due to leakage. Stakeholders appreciate the introduction of some of these strategies
Endorsement by experts	Experts in The Gambia have long term expertise in implementing community water supply systems using borehole and wells that have solar-powered pumping and pipe-borne reticulation systems. The use of Village Water Committees has been found to be appropriate for effective management of water resources as a climate change adaptation measure.
Timeframe	Pipe-borne reticulation systems for one to three districts can take about 3 years to install.
Institutional capacity	Number of technicians to maintain the reticulation systems will need to be increased substantially due to large number of retirees from the public service. Village Water Committees need capacity building on leadership roles and responsibilities, and financial management rules and procedures. These must be supported by an operational manual for leadership accountability and financial auditing. Public-private-partnerships need to be established and to encourage investment by the business sector.
Adequacy for current climate	The technologies to improve availability of freshwater supplies to communities are adequate for current climate. With some improvements (e.g., increases in the depth of boreholes, wells and reservoirs) climate change impacts such as decreasing water tables due to reduction in recharges can be accommodated.
Size of beneficiaries group	Water loss reduction measures and technologies to improve freshwater availability can be implemented at all scales, from the household to the community and regional levels. The technologies to improve freshwater availability for communities are of two types. One well with one or two Hand Pumps is installed for a beneficiary population of about 500 persons. More than 500 persons, a Borehole with a pipeborne reticulation system is installed. The size of the borehole and the number of tap heads installed depends on the size of the beneficiary population. Water-efficient technologies can be adopted at the household and community levels. Water-pricing schemes and water-use efficiency policies, on the other hand, are likely to be adopted by

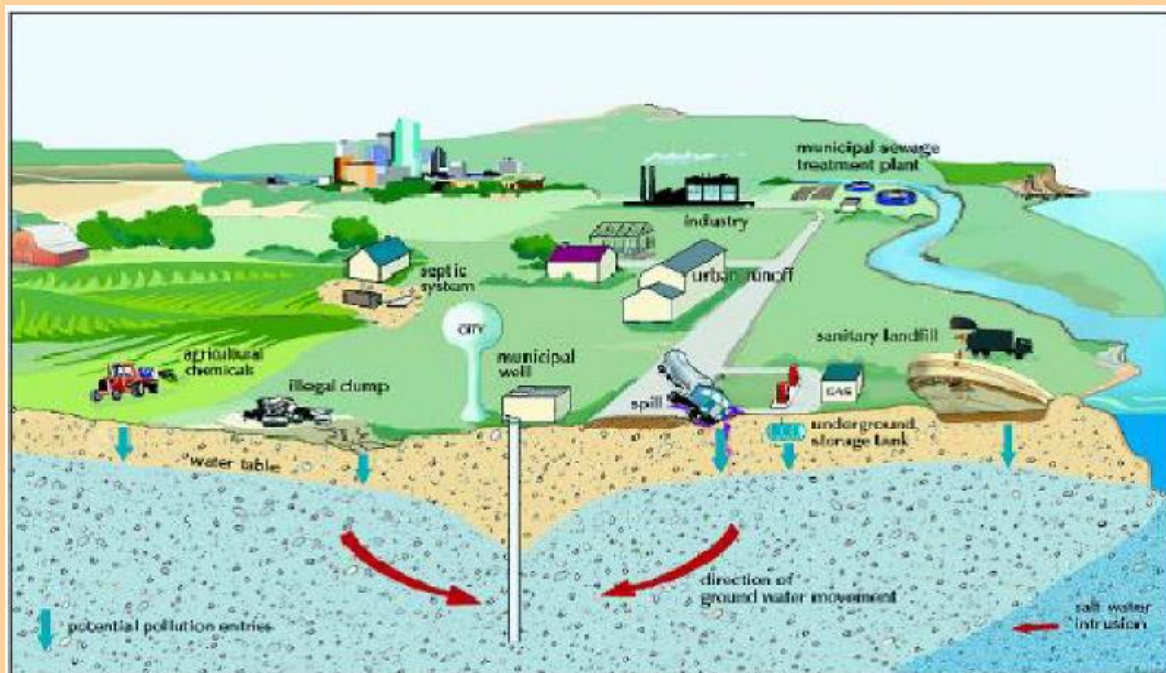


Name of Technology	Relocation of Water Points away from saline, flood and drought prone areas
Sector	Water Resources
Sub-Sector	Water Supply
Introduction	Salinization and contamination of groundwater systems can be caused by fossil salt water, i.e. water that has remained trapped in the sedimentary layer; salt water intrusion from the sea, as a result of over-pumping near the coast, or by reduced recharge due to reduction in rainfall; and water contamination from surface point sources (e.g. pit latrines, dump sites)(van Dongen, 2014). The Gambian open (80km long) and sheltered (200km of inland estuary) coastal zone is experiencing contamination primarily by seawater intrusion due to overexploitation and reduction in freshwater recharge due to reduced rainfall, occasional flooding of traditionally dug shallow water wells and the use of on-site sewage disposal systems, in particular pit latrines, septic tanks and pumping sewer into the River Gambia. The extend of saline intrusion in the River Gambia is mainly governed by the balance of outward advective transport by freshwater and inward dispersive salt transport from Atlantic side, extended with the rainfall rate, which accounts for the local rainfall and evaporation. (Verkerk and Van Rens, 2005). According to Jarju (2009), annual rainfall amounts have decreased by about 30% from 1950 to 2000. This decrease has been evident in the reduction in the length of the rainy season and also the quantity of rainfall amounts recorded in the month of August, particularly during the period 1968 to 1985, and in 2002. The Gambia NAPA (GOTG, 2007) points out that the combinations of sea level rise, global warming and changes in rainfall patterns, could impact freshwater resources qualitatively and quantitatively. Surface evaporation is expected to increase, whilst groundwater recharge is expected to take the reverse trend and both phenomena enhance advective salt transport in the River Gambia (Verkerk and van Rens, 2005; Njie, 2002; as cited by Jarju, 2009), and place additional constraints on management rules of an upstream reservoir. However, the biggest threat of saline intrusion into the River Gambia and coastal aquifers comes from projected sea level rise (Njie, 2002). Flood events from the late 1980s to date are both riverine floods and flash floods. The flash floods affected mostly the Greater Banjul Area (GBA) where the drainage system is very poor, whilst riverine floods occurred in part of Central River Region (CRD) and areas in Upper River Region (URR). In conjunction with sea level rise, shallow water tables, water logged soils and coastal erosion are also adding to flood risk in settlements, such as Old Jeshwang, Eboe Town, and Fajikunda etc, that are steadily encroaching into wetlands (Jarju 2009). In these areas shallow and uncovered wells are completely flooded and conterminated during the floods and for many months after the floods recede. Over exploitation of the groundwater aquifer is mainly due to increased number of water points (wells and boreholes) due to increased demand for human consumption and for horticultural activities. Gambian irrigation using surface water resources primarily from the Gambia River is used only for rice production while mixed crops (vegetables and fruits) are either rain fed or irrigated by using groundwater resources (Jarju, 2009).
Technology characteristics	Key adaptation measures that are pertinent to addressing the climate change related impacts discussed in the preceeding introductory section on the water resources status and management functions include (a) artificial recharge of groundwater aquifers; (b) improvement of management of urban storm-water runoff; (c) promotion of the collection of rain water (harvesting); (d) resettlement of people or relocation of activities away from the flood plains (Njie, 2002); and (e) relocation of Abstraction Points (water wells and boreholes) to less saline areas (GOTG, 2007; Jarju, 2009). In the Kombo peninsula on the coastal zone of The Gambia, where a large number of production boreholes are concentrated, demand is outstripping

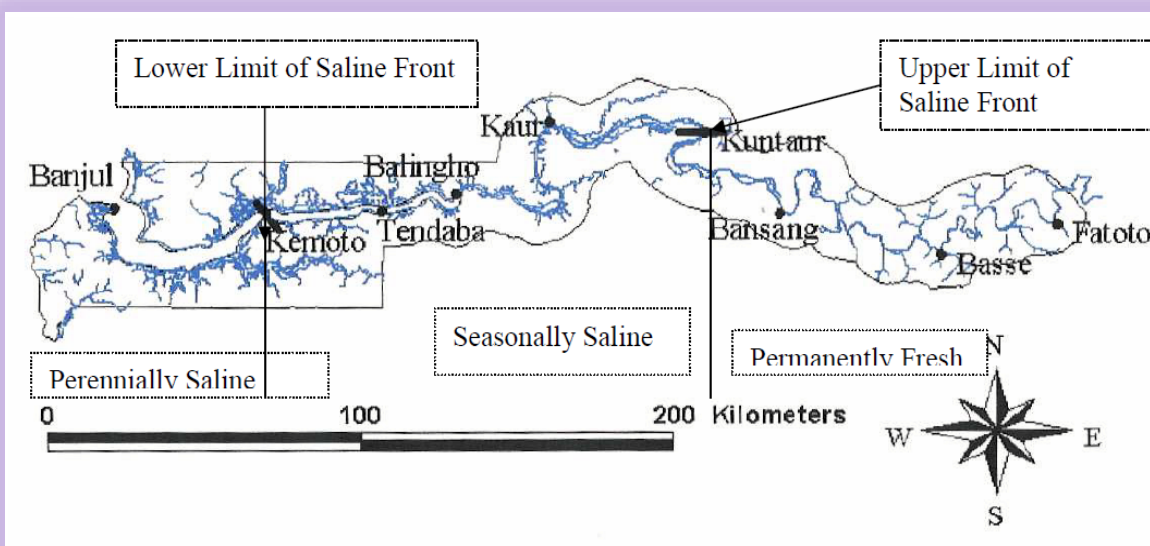
	renewal rates, forcing current and future managers to consider several options including groundwater mining, and long-range transport of water (SNC Lavalin, 2005). According to Manneh (1997), a constant flow of 20m³/s are required to arrest saline intrusion in the estuary at 195km upstream of which 15,000 ha have been identified for irrigation development. Water wells and boreholes that have been found to be too saline for human consumption and crop and livestock watering need to be plugged and abandoned. Replacement boreholes need to be relocated and drilled within a safe distance of the abandoned saline locations and sources such as the sea and the shoreline. Pieter G van Dongen (2014), found that in the coastal zone of Dar-es-Salaam, fresh water (< 150 mg/l) is present beyond 2 km from the sea, but within 1 km from the sea, many boreholes/wells are brackish (300-1,000 mg/l) to brackish-salt (1,000-10,000 mg/l). Funda Dökmen, (2012) also found that seawater intrusion was found within a 1 km radius of the coastal line. This evident relation to distance from the sea clearly points to seawater intrusion as the cause of salinity. Ofcourse, the situation is exacerbated by reduced groundwater recharge due to reduced rainfall amounts and infiltration rates into the ground. Applying a 2Km distance from the source of seawater intrusion as the safe distance may also take into consideration future climate change scenarios. Relocation will include drilling the same number of water points or lesser number landward of the safe distance of 2KM. Relocation of water points will also meet the water supply side adaptation measures identified in the national strategic documents (INC, 2003; Jarju, 2009); GoTG/NAPA, 2007), SNC, 2013) which include (a) the construction of new systems such as well fields and hand-dug wells; (b) modification of existing physical structures such as conversion of diesel powered water pumping systems to solar powered systems and (c) developing alternative management of existing water supply system, for example by changing operating rules, coordinating water supply/demand systems or conjunctive use of surface and ground water supplies. Relocation and modification of technologies will meet the water demand adaptation measures that include (a) conservation and improving efficiency, (b) technology change such as the use of solar power water supply systems in the rural communities and (c) market or price driven transfer activities. For examples, policies which involved metering, water pricing, as well as use of conservation methods, will improve efficiency and promote water loss through demand. In rural Gambia, the communities have service contract with the companies for the operation and maintenance of solar water supply systems. Under this arrangement, community taps are metered and payment is based on the volume of water consumed. This has resulted to efficiency in water use because communities use pipe water supply for drinking and water from traditional wells for laundry and other domestic purposes. This reduces the stress on water withdrawals from the aquifers.
Costs, including	Cost is an important factor to consider in the relocation of water wells and boreholes away from flood-prone and saline areas. From the planning and design stages, climate change issues will be factored in the new structures to make them flood and saline proof. The adaptation scenario is to plug and abandon and then relocate deep wells and boreholes while maintaining the shallow garden wells which do not reach the depth of the saline wedge and are only used for horticultural practices.
• Cost to implement adaptation options ¹⁰	Based on the scenario above, estimated unit cost of drilling one borehole, installing solar powered pumping and distribution systems and running the pipe network for a community of one thousand residents is about US\$42,000, for two thousand residents is about US\$56,000 and for five thousand residents is about US\$120,000, respectively. For a population of less than 500 residents a drilled or hand-dug well fitted with one handpump is estimated to cost about US\$10,000 and for a population of 500 to 1000 residents a dug or drilled well when fitted with two handpumps is estimated to cost US\$14,000.
• Operations and maintenance	The operations and maintenance
Potential financing and markets:	Donor partners such as Saudi-Sahel Programme, the IDB, the AfDB, UNICEF and the EC are always available to support provision of water supply to communities. There has been an increasing number of Small Business Enterprises (SMEs) engaged in the installation and management of water supply technologies such as Hand Pumps, Solar Panels, pipes and taps. The market is growing.
Potential development impacts, benefits	A global warming trend will have serious impact on agricultural production since the resilience of the agricultural system depend heavily on strategic approaches to water management capable of addressing climate change impacts on future renewal rates of groundwater resources, flow and salinity regime of the River Gambia. Cultivation though irrigation with saline water impacts on crop productivity. Salts transmitted into the soil by water affects the growing plants. The osmotic pressure of the soil solution increases because of accumulation of salts in the soil. For this reason, physiological drought occurs because plant roots take in water with difficulty. Salt accumulation within the root zone negatively affects yield and quality of plants over the time (Dokmen and Kurtulus, 2008). Flooding has both direct and indirect impacts on society in terms of loss of assets (physical infrastructure, raw materials, etc.) and indirect impacts in terms of goods and services (lower output of damaged or destroyed factories, cost of medical expenses and lost of productivity arising from increase of diseases, injury or death).
Economic	Relocation of water points from flood and saline prone zones will promote and facilitate adaptation to the negative impacts climate change enumerated above. The technology will reduce the chances of households failing to access potable safe water supplies during floods. It will reduce the time lost traveling long distances to access good drinking water when the water point gets either damaged, contaminated or cannot be accessed because of the floods. Avoiding such loss of time prevents disruption in productive activities and the negative implications this entails. Time loss to morbidity or taking care of a sick relative especially by women due to water borne disease from contaminated water points is also reduced. In the end, there would be a healthy community able to pursue livelihood objectives of its own choice. Relocating the water wells and boreholes to freshwater zones and then backed by adopting appropriate policies and technologies of exporting water for agricultural and domestic use in the saline zones will increase agricultural productivity and reduce pollution from saltwater.

¹⁰ Data and information based on personal communication with the Acting Principal Hydrogeologist of the Department of Water Resources

Social	Areas of concern are domestic dwellings, farms and industry with private supplies. The potential for downward migration of contaminated flood water is high in water abstraction boreholes meaning the spread of illness through the water supply is possible.
Environmental	Relocation of deep wells and boreholes from saline areas will minimize intrusion of saltwater into freshwater zones. However, construction activities will cause damage to soils and vegetation cover.
Status	There is no information regarding the status of the proportion of boreholes and protected wells that can be regarded as resilient to climate change hazards. However, given that awareness to this need has only began to emerge slowly in the last decade, it can be envisaged that a big proportion of the boreholes and wells in flood prone area are vulnerable to contamination and damage due to flooding.
Advantages and disadvantages of relocation of water points from flood and saline prone zones.	Overall the technology will reduce disruptions in access to safe water during flooding. The floodwaters will not only contaminate drinking water sources but also lead to the destruction of water and sanitation systems, increasing the risk for water-borne diseases such as cholera during the rain season. Flooding can lead to contamination of drinking water wells and can also prevent physical access when floodwaters are high enough. Community health and economic activity require continuity of safe water supply. Ensuring continuous access to drinking water decreases the likelihood that populations will be displaced during moderate flooding.
Acceptability to local stakeholders and feasibility of implementation	Both rural and urban water supply are based on policies and regulations that promote and facilitate good practice for digging wells, drilling boreholes and installation of solar powered reticulation systems. Good practice entails that water points are located away or protected from burial sites, pit latrines, runoff water, waste disposal, etc. On top of this, the water affairs department has been encouraging the communities to site the wells in locations which are not prone to flooding.
Endorsement by experts	The water resources experts and managers endorsed the relocation of water points away from saline and flood prone areas of the coastal zone and the estuary of the River Gambia. This endorsement is manifested in the National Communications and the NAPA of The Gambia by inscribing it as one of the adaptation options. The National TNA Adaptation Working Group has also “voted” and prioritized the relocation of water points as viable adaptation option with the accompanying technologies.
Timeframe	The relocation of water points from the planning, designing and implementation phases will take a minimum of 7 years.
Institutional capacity	The Hydrogeology Division of the Department of Water Resources has a wealth of knowledge and skills on water supply technologies particularly as they relate to digging of wells, drilling of boreholes and the procurement and installation water lifting, pumping and distribution systems. The Water Quality Division of the Department of Water Resources and the Water and Sanitation Working Group that includes the Public Health Services of the Ministry of Health and Social Welfare and the Local Councils have knowledge and skills related to public health principles. These institutions are capable of undertaking basic survey and analysis of population distribution; and water point location, elevation and mapping. A training or certification program may be necessary for staff of the Hydrology and Water Quality divisions of the Department of Water Resources to enable the determination flood-prone and saline areas under current and projected climate change. Some institutional capacity is necessary to determine if, where and how public funds should be allocated for constructing or retro-fitting wells.
Adequacy for current climate	Plugging and abandoning water points that have become saline and are in flood prone areas have been practiced at a smaller scale but have proved to be inadequate in addressing the water stress caused by the contamination of water by salt and other bacteriological and chemical components of pollution.
Size of beneficiaries group	Considering that the Kombo Peninsular is defined as the Coastal Zone of The Gambia, it is estimated that the population that will benefit from relocation of water points will be about 53% of the population of the Gambia (GBoS, 2013, http://www.accessgambia.com/information/population.html)



Sources of groundwater contamination are numerous and are as diverse as human activities (Zaporozec and Miller, 2000, and Zaporozec, 2004; as cited in Pieter G van Dongen, 2014)



Zonation of the River Gambia Estuary Source: Njie & Corr 2006

Name of Technology	Artificial Groundwater Aquifer Recharge
Sector	Water Resources
Sub-Sector	Water Supply
Introduction	Artificial recharge of groundwater aquifer is important for the storage of surplus surface water due to excess stormwater runoff underground to serve growing populations demand for more water under a warming and drier climate as projected for The Gambia. The recharge is also useful in mitigating or controlling saltwater intrusion into coastal aquifers.
Technology characteristics	The main purpose of artificial aquifer recharge technology is to store excess water for later use, while improving water quality (decreasing the salinity level) by recharging the aquifer with better water. The artificial recharge techniques in common use include the following:

	• Infiltration Basins and Canals of a particular volume are used to recharge a corresponding volume of an aquifer. Canals may be more efficient than the infiltration basins because high circulation velocities in the canals precluded the settling of fine material and result in higher infiltration rates. • Water Traps are earthen dams of variable height that are constructed of locally available materials and are used to increase infiltration in streambeds. Their storage capacities fluctuate between 250 and 400 m³ and, given proper maintenance, they have an estimated life span of 20 to 25 years. • Cutwaters are excavations of variable dimensions, used as reservoirs, built in low-lying areas. The primary objective of this cutwater technology is the harvesting of surface waters. Cutwaters used for artificial recharge are built on top of permeable strata but those used for surface water storage are built on impermeable substrates. • Drainage Wells or "suckwells" are used to dispose of drainage waters. Their depth is determined by the well digger and is based on reaching an adequate fissure or "suck" in the rock. The wells are constructed either square or circular in shape and are provided with guard walls of concrete above the ground surface and drainage ports or underground pipes or culverts to conduct runoff into the wells. • Septic Tanks and Effluent Disposal Wells serve as other technologies for artificial groundwater recharge but basically consist of effluents from soakaways in septic tanks; • Sinkhole Injection technologies utilize treated and excess surface runoff in karstic limestone aquifers, which are commonly associated with seawater intrusion and are highly saline. The recharged water is monitored through a series of monitoring and production wells. Monitoring is carried out to measure changes in groundwater levels and water quality (salinity levels). Most of the freshwater supply for animal and human consumption in The Gambia, especially in the western half of the country comes from groundwater and the major source of recharge is rainfall. Current rainfall variability and its projected decrease under climate change will not allow for a sufficient level of aquifer recharge by natural means. Thus, the technologies discussed in this factsheet will provide for the artificial enhancement of the natural recharge.
Costs, including	
Cost to implement adaptation options	• Capital cost of basins and canals is estimated at \$31,300. The production cost is \$0.20/m³. • The water traps are estimated at between \$133 and \$167. • The capital cost of a 5,700 m³ cutwater, equipped with a 14 m extraction well, is estimated at \$6,325. • The initial capital cost of the sinkhole injection system is estimated at less than \$15,000.
Operations and maintenance	• Infiltration basins and canals require minimal maintenance, consisting mostly of using a bulldozer to remove accumulated sediments and to rehabilitate the system; • Water traps require maintenance during the first few years of operation, until the natural vegetation grows again in the area; • Maintenance of cutwaters include removal of large loads of sediment deposited in cutwaters during dry periods; the operation and maintenance cost is estimated at \$248 per year. The production costs are estimated to be about \$0.30/m³ for the first five years of operation, \$0.17/m³ for the next five years (five to ten years of operation), and \$0.15/m³ for the following five years (ten to fifteen years of operation). • Maintenance of suckwells is labor-intensive and generally involves the removal of silt, which accumulates at the bottom of the well and may plug the "suck", rendering it useless. Owing to increased labor costs and declines in profitability at most sites, suckwells may not be viable. • In sinkhole injection, operations are simple. The earth canals need to be kept clear to ensure maximum delivery of water. The settling basin has to be cleaned of accumulated sediment and vegetative growths once every four to five months. Vandalism, resulting in damage to sluice gates, sinkholes, and monitor wells, is also a problem in the maintenance of the system. Maintenance costs are low, under \$3,500/year.
Potential financing and markets:	There are opportunities to use private well digging companies in construction of the structures used for groundwater aquifer recharge. The Horticulture Unit of the Department of Agriculture can facilitate access to finance for installation of the technologies on the Kombo Peninsular where abstraction of water is close to tipping point and the aquifers need to be recharged.

Potential development impacts, benefits	Groundwater recharge produces a number of economic, social and environmental co-benefits.
Economic	Aquifer recharge increases freshwater availability for agricultural activities particularly in horticulture which is practiced by women during the dry season. Use income is generated from these activities.
Social	Income generated from horticultural activities is used to pay for school fees and for medical attention. Women also use some of the money to buy clothes to attend social gatherings.
Environmental	In general, most wells influenced by artificial recharge have shown declines in salinity levels. Recharge methods are environmentally attractive and create a number of other environmental co-benefits. During the construction of water traps, disturbances of soil and vegetation cover may cause environmental damage to the project area. There is a potential for contamination of the groundwater from injected surface water runoff, especially from agricultural fields and roads surfaces. In most cases, the surface water runoff is not pre-treated before injection. Recharge can degrade the aquifer unless quality control of the injected water is adequate.
Status	Aquifer recharge is not practiced in The Gambia at operational level. However, there are potentials for the rivers to recharge the underlying groundwater aquifer during the three-month rainy season period. Cutwaters can be used in rangelands, degraded lands, forests, and national parks and sinkholes can be used in residential areas to encourage infiltration of rain water into the ground and aquifers.
Advantages and disadvantages of aquifer recharge	Replenishment and storage of rain and runoff water in underground aquifers of The Gambia using the technologies discussed in this factsheet have the following advantages and disadvantages. Advantages include: • Most of the technologies are simple, appropriate and will generally be well understood by both the technicians and the general population; • A lot of the rainwater that falls and runoff to the sea during the wet season will be captured, stored and available for use in the dry season, when demand is highest. • The recharge will significantly increase the sustainable yield of the two aquifers of the country. • Utilization of the technologies support the management of surface water runoff and thus reduces erosion, loss of top soil and sedimentation problems in farms and fish spawning grounds. Disadvantages include: • Recharge with effluents may not be culturally acceptable especially when the groundwater stored is used for agriculture and livestock watering; • In the absence of financial incentives, laws, or other regulations to encourage landowners to maintain drainage wells adequately, the wells may fall into disrepair and ultimately become sources of groundwater contamination; • Where significant volumes of water are not available to inject into the aquifer, groundwater recharge may not be economically feasible.
Acceptability to local stakeholders and Feasibility of implementation	The Gambia being located in the Sahelian zone of West Africa requires replenishment and storage of water through artificial recharge of her groundwater aquifers. Implementation of the technologies is feasible and will be acceptable to the stakeholders. There would, however be reservation in the utilization of the water if effluents from soakaways of septic tanks are used as source of recharge.
Endorsement by experts	Experts in The Gambia have long term expertise in implementing community water supply systems using borehole and wells. Private contractors that construct these water points can easily be capacitated to be involved in the construction and implementation of the aquifer research technologies discussed in this factsheet. The experts will benefit from capacity building on experimental studies to quantify the recharge provided by different technologies and will easily endorse the adoption and implementation of the technologies.
Timeframe	As these technologies have been implemented in many parts of the world there would be little feasibility and piloting in The Gambia. Adoption and implementation may take about 3 to 5 years.
Institutional capacity	The Hydrogeological Division of the Department of Water Resources, Soil and Water Management Unit of the Department of Agriculture and the Horticultural Unit of the Department of Agriculture will need institutional capacity building, including human capital to adopt and implement the technologies for aquifer research. Experts will need capacity building in the assessment and monitoring of the volume aquifer and to determine the level at which recharged is required. The experts would also need capacity building in determining the most viable technologies for aquifer recharge.
Adequacy for current climate	The technologies reported in this factsheet are adequate for current climate. The technologies may need to be adjusted to collect more water under the projected climate change.

Size of beneficiaries group	Aquifer recharge is applicable at the watershed level. However, priority must be given to the coastal area of the North Bank Region and the Kombo Peninsular (Greater Banjul and the Kombo Districts of West Coast Region).
------------------------------------	---

Annex II: List of stakeholders involved and their contacts

Name	Title and Organization
Bubu Pateh Jallow	National Consultant
Momodou Dumbuya	
Lallah Badgie	
Yayah Baldeh	Department of Livestock
Mass Njie	Department of Agriculture
Fatou Sillah	Kanifing Municipal Council
Lamin Jatta	Gambia Technical Training Institute
Lamin Mai Touray	Department of Water Resources
Ebou Mass Mbya	Department of Fisheries
Dr. Momodou Njie	National Consultant
Lisa Jarju	Project Assistant