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TECHNOLOGY NEEDS ASSESSMENT REPORT

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Liberia Technology Needs Assessment Report

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Foreword

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

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

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

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

LIST OF ACRONYMS

AfT	Agenda for Transformation
ASWG	Adaptation Sectorial Working Group
CDA	Cooperative Development Agency
CAADP	Comprehensive Africa Agriculture Development Policy
CARI	Central Agricultural Research Institute
CSO	Civil Society Organization
CU	Cuttington University
DNA	Designated National Authority
DTU	Danish Technical University
EPA	Environmental Protection Agency
EST	Environmentally Sound Technology
EVD	Ebola Virus Disease
FAPS	Food and Agriculture Policy and Strategy
FDA	Forestry Development Authority
GEF	Global Environment Facility
GDP	Gross Domestic Product
GHG	GreenHouse Gases
INDC	Intended Nationally Determined Contribution
ITCZ	Inter-Tropical Convergence Zone
IWRMP	Integrated Water Resource Management Policy
LACRA	Liberia Agriculture Commodity Regulatory Authority
LADA	Liberia Agribusiness Development Activity
LASIP	Liberia Agriculture Sector Investment Program
LISGIS	Liberia Institute for Statistics and Geo-Information Services
LNRDS	Liberia's National Rice Development Strategies
MCA	Multi-Criteria Analysis
MIA	Ministry of Internal Affairs
MOA	Ministry of Agriculture

MSME	Small and Medium Enterprises
MSP	Multi-Stakeholder Process
NAPs	National Adaptation Programs
NCCSC	National Climate Change Steering Committee
NCCS	National Climate Change Secretariat
NCSS	Liberia National Cassava Sector Strategy
NCSCC	National Cassava Sector Coordinating Committee
NDMP	National Diaster Management Policy
NEP	National Energy Policy
NESF	National Energy Stakeholder Forum
NFSNS	National Food Security and Nutrition Strategy
NGO	Non-Governmental Organization
NRFL	National Rice Federation of Liberia
PAPD	Pro-Poor Agenda for Prosperity and Development
PRS	Poverty Reduction Strategy
PPPs	Public-private partnership
RCMs	Regional Climate Models
SAPEC	Smallholder Agricultural Productivity Enhancement and Commercialization
SDGs	Sustainable Development Goals
STAR	Smallholder Agriculture Transformation and Agribusiness Revitalization
SWGs	Sectorial Working Groups
TAP	Technology Action Plan
TFS	Technology factsheet
TNA	Technology Needs Assessment
UDP	UNEP DTU Partnership
UL	University of Liberia
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
USAID	United States Agency for International Development
WAAPP	West Africa Agricultural Productivity Project

EXECUTIVE SUMMARY

Liberia lies within the humid Upper Guinean Forest Ecosystem in West Africa on the Atlantic Coast. Within its borders, 15,050 km^2 consist of water, and the remaining 96,319 km^2 are land. The country shares a border with three countries. Côte d'Ivoire is to the east; Sierra Leone is to the west; and Guinea is to the north. Like most Sub-Saharan African economies, the majority of the Liberian population relies on subsistence agriculture, while exports predominately consist of raw commodities such as rubber and iron ore. Local manufacturing, such as it exists, is mainly foreign owned.

Even though Liberia's total emission of greenhouse gases is insignificant in global setting, it is extremely vulnerable to the impacts of climate change. Hence, the TNA project in Liberia has selected three sectors for both adaptation and mitigation to climate change, wherein one out of the three sectors analysed in this report deal with adaptation technologies. The sectors selected are; the Agriculture sector, Coastal zone sector, and the Energy sector. The Energy sector has been identified as the priority mitigation sector because it accounts for around 67.5% of the national total GHG emissions. However, this report focuses on the agriculture sector which account for about 31.9 % of GHG emissions.

Liberia is home to many endangered and endemic species, the country continue to maintain vast majority of its forest through conservation and sustainable forest management. However, climate change is already impacting all sectors especially the agriculture sector which has been selected for adaptation in the TNA project. The selection of priority sectors in the TNA project is align with national development agenda especially the Pro-Poor Agenda for Development and Prosperity, while also considering the vulnerabilities of climate change impacts on Liberia.

The sector prioritization took into account sectors that are earmarked in Liberia's Initial National Communication as well as the most talk-about project the National Adaptation Pograms (NAPs) that deals with climate change from sectorial level to a policy and strategic perspective, the TNA project is complementing existing efforts in terms of nationally appropriate technology options.

This TNA report presents technology needs for adaptation in the agriculture sector. A multi-stakeholder process (MSP) has been adopted for the identification and prioritisation of technological options using a linear additive Multiple Criteria Analysis (MCA) framework. All relevant information for prioritising technologies was provided in Technology Fact Sheets. The criteria proposed by MCA4Climate were used in MCA, and indicators were defined by local stakeholders. The technologies that have been retained for developing the Technology Action Plan (TAP) are listed below:

- Value addition to agriculture products;
- Improved Storage (drying and freezing of agriculture products); and
- Integrated Soil Fertility Management

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CHAPTER ONE: ABOUT THE TNA PROJECT

1.1 About the TNA project

The TNA project has been on-going and many developing country parties have participated from Phase I, Phase II and Phase III. Liberia joined the TNA project in Phase III and it is important to note that this is Liberia's first TNA project. The country is proposing an applied process to leverage funding for the implementation of prioritized technologies for climate change mitigation and adaptation in the Agriculture, Energy and Coastal Erosion sectors. The main focus of the project will be on TAPs which will pave the way for the transfer of environmentally-sound technologies, and their diffusion and adoption. Liberia's TNA report has prioritized mitigation and adaptation sectors and has prioritized technology options in these sectors.

The purpose of the TNA project is to assist participant developing country Parties identify and analyze priority technology needs, which can form the basis for a portfolio of environmentally sound technology (EST) projects and programs to facilitate the transfer of, and access to, the ESTs and know-how in the implementation of Article 4.5 of the UNFCCC.

The TNA project seeks to identify and prioritize through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities (TNA).

In Liberia, the TNA project consists of the TNA Coordinator and three consultants. The country has identified and prioritized three sectors for both adaptation and mitigation goals. The sectors prioritized for adaptation include Agriculture and Coastal while the Energy sector was selected for mitigation. The process that led to the identification of the three sectors was carried out based on the participation of stakeholders drawn from various ministries and agencies of government, NGOs, CSOs, Private sector and individual experts of Liberia.

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

There exist several national policies and strategies formulated over time, by the Government of Liberia relating to technology innovation, economic growth, development priorities, and adaptation to climate change, natural resource management, and improvement of social welfare. Prominent amongst them are:

Poverty Reduction Strategy (PRS) covering the period 2008-2011

The Liberia's Poverty Reduction Strategy (PRS) or "Lift Liberia Policy" presents the Government's vision and major strategies for moving towards rapid growth and development during the period 2008-2011 (GOL, 2008). The overarching aim is "to build a new nation that is peaceful, secure, and prosperous, with democratic and accountable governance based on the rule of law, and with abundant economic opportunities for all Liberians" (GOL, 2008).

Agenda for Transformation (AfT)

The Agenda for Transformation is Liberia's five-year Medium-Term Economic Growth and Development Strategy (2012 -2017) (GOL, 2012). The AfT is the first step in achieving the goals set out in Liberia Rising 2030, Liberia's long-term vision of socio-economic development, and sets out precise goals and objectives that Liberia will achieve in the next five years in order to take the necessary steps toward its long-term goals, which are to become a more prosperous and a more inclusive society (GOL, 2012).

National Environmental Policy of 2003

The overall goal of the national environment policy is to ensure long-term economic prosperity of Liberia through sustainable social and economic development, which enhances environmental quality and resource productivity on a long-term basis that meets the requirements of the present generation without endangering the potential of future generations to meet their own needs (EPA, 2003). The aim of the national environmental policy is to ensure the improvement of the physical environment,

improvement of the quality of life, and of the people, improvement of the economic and social living conditions of the entire citizenry, and present and future generations (EPA, 2003).

Liberia National Forestry Policy and Implementation Strategy of 2006

This policy is woven around several strategic objectives, ranging from the integration and balancing to optimize the economic, social and environmental benefits from the forest resource; to ensuring that forestry development contributes to national development goals and international commitments (including regional cooperation and trans-boundary issues) and is coordinated with other relevant branches of government (FDA, 2006).

National Mineral Policy of Liberia

The main strategies of the current Government are to revive the mineral sector to enhance its contribution to government revenues, foreign exchange earnings, employment creation, ancillary economic activities, human resources and technology development and the improvement of social and physical infrastructure (GOL, 2010).

National Energy Policy of Liberia

The National Energy Policy (NEP) is the product of an extensive process of consultations that started with the National Energy Stakeholders Forum (NESF) in October 2006 (GOL, 2009). The principal objective of the NEP is to ensure universal access to modern energy services in an affordable, sustainable and environmentally-friendly manner in order to foster the economic, political, and social development of Liberia (2009).

Food and Agriculture Policy and Strategy (FAPS- 2008)

In further commitments to the objectives of ensuring food security, the government of Liberia carved, in July 2008, developed the Food and Agriculture Policy and Strategy (FAPS) to address the superfluity of problems that have historically affected agriculture and its linkages to the other sectors in a coherent, consistent and forward-

looking manner (MOA, 2008). It presents a pro-poor and pro-growth framework to transform the sector from perennial state of subsistence to one of sufficiency (2008).

National Food Security and Nutrition Strategy (FSNS- 2009)

The key objective of the FSNS is to make certain that "all Liberians have reliable access to the food they need to live active and healthy lives" (MOA, 2009). Although the strategy encompasses the food security and nutrition needs of all Liberians, it prioritizes the needs of food for insecure and nutritionally vulnerable groups in the society, including the elderly who have little support, female-headed households, orphans, and HIV-affected individuals (MOA, 2009). The FSNS addresses four separate dimensions of food security, namely, food availability, access to food, utilization and vulnerability (MOA, 2009).

Liberia Agriculture Sector Investment Program (LASIP- 2009)

The LASIP- 2009 seeks to transform Liberian agriculture and, in so doing, maximize the sector's contribution to national economic growth, employment and income generation, food and nutrition security, and poverty reduction (MOA, 2009). To overcome pervasive structural impediments and a poor policy environment that have undermined agricultural growth and development, LASIP adopts a pro-poor approach to raising agricultural productivity, strengthening institutions, and making markets work for households and communities through commercialization and private sector initiatives (MOA, 2009).

Integrated Water Resources Management Policy (IWRMP 2009)

The policy covers two broad areas: water resource management and water resource use (GOL, 2009). The goals are to ensure: (i) full socio-economic benefits for present and future generations; (ii) access to safe and adequate water for the people; (iii) the availability of quantity and quality of water for the environment and ecology; (iv) the availability of sufficient quantity and quality of water for food security; (v) the availability of water for other uses such as hydropower generation, industry, transportation, recreation, etc (GOL, 2009).

The New Policy for Agricultural Advisory Services of 2009

The policy for agricultural advisory services is to provide the legal and enabling framework for transforming and strengthening a broad-based, pluralistic system (MOA, 2009). While this new policy for agricultural advisory services in Liberia is recognized as the way forward for reforming the current top-down system in the long term, the strategy for implementation should be carried out on a pilot basis in selected counties and districts using multi-stakeholder learning approaches to assess its wider suitability to the Liberian conditions (MOA, 2009).

Land Rights Policy of 2013

The Land Rights Policy of Liberia is premised on the former Land Commission's policy recommendations for land rights in Liberia, centered on four basic types of rights: Public Lands; Government Lands; Customary Lands; and Private Lands (GOL, 2013).

The legal ownership of land will provide security of tenure to land users and holders thus giving those rights to sustainably manage and use their lands (GOL, 2013).

National Disaster Management Policy of 2012

The National Disaster Management Policy provides an overall framework for disaster management in Liberia (GOL, 2012). The NDMP particularly aims at integrating risk reduction as appropriate into development policies and planning at all levels of government, including the environment, land, agriculture and forestry sectors, as well as Liberia's new development agenda, the Pro-poor Agenda for Prosperity and Development (GOL, 2012).

National Policy and Response Strategy on Climate Change of 2018

The National Policy and Response Strategy on Climate Change is a vehicle developed to support climate change adaptation, disaster risk management and mitigation capacity in Liberia (EPA, 2018). It focuses on the implementation of Liberia's

commitment to achieving the Sustainable Development Goals (SDGs), especially Goals 13, 14 and 15 (EPA, 2018).

Pro-Poor Agenda for Prosperity and Development 2018 to 2023 (PAPD)

The Pro-Poor Agenda for Prosperity and Development focuses on strengthening the capacities of the people to thrive and further draws all Liberians into the national development process (GOL, 2018). The PAPD, which is a five-year national development plan, intends to address the basic needs of Liberians for income security, better access to basic services, and greater opportunities for self-improvement in an enabling environment that is inclusive and stable with the long-term aim of raising per capita income levels and economic status of Liberia to a middle-income country as outlined under the Vision 2030 framework (GOL, 2018).

Liberia's Nationally Determined Contributions (NDC) 2015

In Liberia's NDC, it was revealed that Liberia is faced with climate change and variability leading to extreme events that have negative impact on agriculture, forestry, health, energy and other sectors (EPA, 2015). It outlines various Climate change impacts such as irregular patterns of rainfall, flooding, high temperature, and coastal erosion that resulted to crops and livestock losses which intensify food insecurity and loss of income (EPA, 2015).

1.3 Vulnerability assessments in the country

Up to date, about three major climate vulnerability assessments have been carried out in Liberia. The first was conducetd in 2008 (EPA, 2008), the second in 2013 (USAID, 2013) and the third in 2019 (EPA, 2019).

The 2008 assessment conducted by the EPA focused on development challenges and vulnerability to climatic variability. It was established that much of the effects of increasing climatic variability and climatic change threaten key economic sectors in Liberia were agriculture, fisheries, forestry, energy, health, meteorology/hydrology (EPA, 2008). Production systems in each of these sectors have already experienced reduced productivity that is linked to changing climatic patterns (Wiles, 2005).

The USAID 2013 assessment delved into both social systems vulnerability and natural systems vulnerability.

In the social systems vulnerability, the current condition of the population was assessed using past survey data and the 2008 census (LISGIS, 2008) to develop a social vulnerability index that could be displayed spatially. It was reported that most rural households are food insecure, meaning that they lack access at all times of the year to sufficient, safe, and nutritious food to meet their dietary needs; nationally, 80% of the rural population was either moderately vulnerable (41%) or highly vulnerable (40%) to food insecurity (USAID, 2013).

The Social Vulnerability Classification was constructed from 18 spatially referenced variables based upon county-level 2008 census data or other reports, and the analysis of social vulnerability focused on 12 social attributes at the district level from census data including: Displaced Population, Distance to Improved Drinking Water, Distance to Medical Facility, Illiterate Population, Households not involved in Fishing, Households Lacking Furniture, Households with no Livestock, Households Lacking a Mattress, Households with no Poultry, Substandard Housing, Unimproved Drinking Water Source, and Unimproved Sanitation (USAID, 2013).

The natural systems vulnerability assessment was limited to four sectors, including Agriculture, Forests, Fisheries and Coastal Areas. Resource vulnerability was examined at the national level in terms of current stressors, primarily development pressure on forests and protected areas, overfishing, and climate hazards such as higher temperatures, altered rainfall patterns and sea-level rise. It was reported that climate change impacts on natural forested ecosystems, especially protected areas, are exacerbated by short-term stresses from development activity. Many of these stressors manifest throughout the country (e.g., heat stress) but some, such as coastal erosion, are limited to one region. Similarly, some resource systems are impacted by most stressors but in different ways depending on the resource subsystem, such as agriculture (e.g., small holder versus commercial operator).

The third assessment conducted in 2019 focused on three sectors; Agriculture, Fisheries and Forestry. For the agriculture sector, it is reported that farmers in Nimba

and Grand Gedeh Counties have observed that warmer temperatures have led to reduction in chill hours potentially reducing yields for some crops like maize, rice, rubber, and cassava (EPA, 2019). This is so, for every $1^{o}C$ increase above $30^{o}C$ temperature per day during maize growing season, there is a corresponding 1% reduction in yield each day under optimal rain fed condition (ACPC, 2014). Besides temperature increase, it was also observed that due to fluctuation in rain patterns, farmers are finding it difficult to make farming decisions due to the rain intensifying in the early stage of the rainy season (EPA, 2019).

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

Expected Climate Change

Liberia lies within the Inter-Tropical Convergence Zone (ITCZ) and has two major seasons: rainy season (May-October) and dry season (November-April). With a tropical climate and a territorial area of 111,369 km^2, the dry land of Liberia extends about 96,160 km^2 (USDA, 2013). The country has six major rivers namely: St. John, St. Paul, Mano, Lofa, Cavalla and Cestos, with several tributaries emptying into those rivers thus making its soil and environment moist all year round (USDA, 2013).

Temperature - based on historical records available from 2009 to 2012 at the Roberts International Airport weather station, the mean daily temperature typically varies from 23°C to 33°C and is rarely below 21°C or above 34°C over the course of the year (EPA, 2013). The records show that there is a warm season that runs from January 1 to May 8 with an average daily high temperature above 31°C. There is a cold season, which runs from July 6 to September 17 with an average daily high temperature below 28°C (USDA, 2013).

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

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

Rainfall - Liberia has a rainy season that runs from May to October due to the African monsoon and has frequent rains in other months, except in the short dry season that runs from December to February, which is more marked in the north. In the southern zone, the rains have a relative break from mid-July to late August. Rainfall along the coast exceeds 3,000 millimeters per year. In Monrovia, the northern part of the coast, rainfall reaches 5000 mm per year with a maximum in June and July, when nearly 1000 mm of rain per month falls, follow by a relative decrease in August. Here the rains are abundant already in April, and still in November. In the interior precipitation it is less abundant, and it drops below 2,000 mm per year (EPA, 2013).

The average increase in the 2020s for rainfall is estimated at 3% (EPA, 2013). Comparing the current to 2050 spatial pattern of average annual precipitation, other projection also shows that there will be a slight increase in total rainfall towards the inland in the future, with the greatest average annual precipitation (5,000 mm) projected along the western coast in 2050. It is also projected that there will be an increase in rainfall along the coast during the wet season while the inland regions will

see normal to slightly reduced rainfall. Due to the projected increase in temperature in the ocean by 2050, the northern parts of Liberia will experience drier conditions, while rainfall along the southern coast will increase in May. June is reported to also have increase rainfall along the coast with the stronger monsoon pushing rainfall farther in the interior; and the northern interior will experience pockets of dry conditions. In July, which is the start of the mid-dry season period, there will be a dramatically expanded area of dryness to the east, while rainfall along the coast will continue to increase. In August, there will be little change in rainfall pattern but with drier conditions for northern Liberia, reflecting a shift in the pattern of the rain season. These projections show a spatial variability in precipitation with a warmer Atlantic Ocean and reduced inland temperature that result to less rainfall in the interior. The USDA ensemble modeling projections of rainfall among three representative meteorological stations also gave mixed and inconclusive results, lacking consistency and predicting decreases and increases in rainfall across stations. With the warming projected, an increase in rainfall is the most likely outcome from a dynamics perspective (EPA, 2013).

Impacts on Sectors Vulnerable to Climate Change

Agriculture

The agriculture sector of Liberia is labor intensive and characterized by low technologies and productivity with accompanying high food deficits. Agriculture-related imported products account for over half of total national imports since 2005 (EPA, 2018). The majority of the rural population of Liberia depends almost entirely on food crop production as an important source of livelihood. The system of production is rain-fed, indicating heavy dependence on rainfall. Increasing tendency of changes in rainfall pattern, and temperature has significantly impacted the sector. In the absence of regular supply of water, all metabolic processes stop apparently causing extensive damage and loss to the farmers and food insecurity in the nation (EPA, 2018). Moreover, drought can destroy flowers and flowering processes. In addition, climate change induced hazards, such as animal diseases and disease vectors could affect the productivity of the livestock sub-sector (EPA, 2018).

Forestry

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

Fisheries

Although there have been no recent stock assessment conducted in Liberia, fisheries continue to provide a significant proportion of the animal protein needs of the country. Climate change variability can adversely impact aquatic bodies and subsequent destruction of water organisms, thereby seriously threatening fishery production. It has been estimated from several studies that the combined effect of changing temperature and rainfall patterns has markedly affected fish stock in terms of declining levels of certain species. It has been predicted that climate induced changes in the biophysical characteristics of Liberia, along with extreme events, will have significant effects on the ecosystems which support especially inland fish production (EPA, 2018). Over 80% of the population of Liberia relies on the fisheries sector for animal protein (FAO, 2009). The actors in the fisheries sector are;

- The local artisanal fisher group is the Kru.
- The migrant fishermen (Fanti and Popo).
- The industrial fishers mostly foreigners.

However, fisheries data available from 2004 estimated about 11250 persons involved in fisheries, including full-time and part-time, sport fishers and fish dealers. Fish farmers accounted for about 1050 involved with aquaculture (FAO, 2007).

There are about 11 250 persons involved in fisheries, including full-time and part-time, sport fishers and fish dealers. There are currently 1050 fish farmers (FAO, 2007).

The sustainable yield of Liberia's continental shelf prior to the 14 years of civil conflicts accounted for about 180 000 t/year for marine, and 40 000 t/year for freshwater (FAO, 2007). After the war, catch reduce to 10300 and 11700 t/year from 2000 up to 2004. Fish stock assessment carried out in 1986 estimated the total biomass of both pelagic and demersal species at 800 000 t (FAO, 2007).

Health

Considering the poor state of the country's health care delivery system, and low health standards, increasing temperature is likely to exacerbate disease incidence to the extent to overwhelm the system. Climate-sensitive diseases could also be on the rise. Moreover, the impact of rise in average temperature and heat stress can cause serious skin irritation and rash. This can impair human health and productivity. In Liberia's Initial National Communication, it is reported that climate induced vector-borne diseases such as malaria, cholera, diarrheal, trypanosomiasis, yellow fever, lymphatic filariasis, Lassa fever, schistosomiasis, hepatitis A, and intestinal worms are likely to increase by 10% by 2100 (EPA, 2013).

Gender

The impact of gender disparity is glaringly visible in Sub- Saharan Africa and across all sectors of government and the private sector (Whitehead & Tsikata, 2003). While women and children are recognized to be striving for equality and integration, their men counterparts are equally facing various levels of inequality and marginalization in the society (Canny, 2015).

According to WBGDG, (2010) women comprise over half of the agriculture labor force; and their role in agriculture is important, particularly in food crops, where they are reported to produce over half of the outputs; their production of cash crops is limited. Access to resources and markets is also significantly constrained across the population; but in the specific case of women, they are particularly affected due to their multiple economic and domestic activities (WBGDG, 2010).

Men and women in Liberia are traditionally involved in the labor-intensive agricultural practices, although at varying levels, without any forms of protection against diseases, extreme weather and other climatic conditions (MOA, 2009). Climate change will have far reaching consequences on their health, livelihoods and survivability (EPA, 2018).

Infrastructure

Liberia has a low infrastructure capacity for basic social services, making the country highly vulnerable to climate change. In 2005, it was projected that a rise in sea level by 1 m, would cause a loss of about 95 km^2 of the estimated 565-km long coastline (due to inundation); and 50% of the area inundated (48km^2) will be areas with settlement such as parts of the capital city of Monrovia, River Cess, Buchanan, and Robertsport, which are less than 1 m above mean sea level (Wiles, 2005). This was projected to result in a loss in infrastructure and land of around $250 million apart from the social and psychological stress to the population, with women and children being particularly vulnerable.

Energy

A huge majority of the Liberia's population depends on biomass, particularly on firewood and charcoal, for cooking and heating needs and on palm oil for lighting. According to GoL (2012) about 2% of the rural and 10% of the urban population have access to electricity through diesel generation. The use of modern energy sources like petroleum products and electricity generated through diesel is mainly limited to the economic sectors and transportation. However, Liberia has the potential to diversify its energy potential using its abundant renewable energy resources such as hydro power, biomass and solar power. For instance Liberia's six rivers (Mano, Saint Paul, Lofa, Saint John, Cestos and Cavalla) drains over 60% of the country's area have potential for hydropower. Despite this potential for modern and renewable source of energy, fuel wood and charcoal remain by far the most important energy source in the country (USDA, 2013). The threat of climate change on the energy sector in Liberia can be explained in terms of its potential for infrastructural damage on power stations and power transmissions, as well as barrier to access biomass fuel sources which can

be caused by sea level rise and flooding. This can also be explained in terms of the rise in temperature, particularly given that energy source in Liberia is less diversified and dominated by fossil fuel, charcoal and wood. Therefore, the energy sector in Liberia is highly sensitive to the changing climate.

Mining

Mining activities are widely distributed in geographic location although some minerals can occur in association with the others. Due to their widespread nature, climate change explained in terms of shift in rainfall and temperature and extreme events in weather and climate-like flood, affects the effectiveness and stability of the sector. It disrupts infrastructure, transport routes, environmental protection, site closure as well as water and energy supply (Julia N. & Ryan S., n.d). In the 1960s and 1970s, Liberia was one of the major largest exporters of iron ore. Several other types of unexplored minerals are also available in the country. Mining activity in Liberia can be grouped into two major groups, and the challenges associated with it in relation to climate change aggravation are: 1) Industrial mining: which has major overlaps with protected areas/forest reserves causing siltation of dams and rivers, indiscriminate deforestation, ground and surface water pollution, dust pollution, water table depression, habitat fragmentation, depletion of wild resources, and land degradation; 2) Artisanal mining: which typically involve the digging of pits within alluvial river channels and excavating black sands that are associated with diamond-bearing gravels. Nearly every coastal community has a sand pit but there are no estimates of the actual amount of sand being taken from the pits. At the beach mining sites it is reported that the sites are open (and busy) 24 hours per day. This situation is causing coastal erosion, shoreline recession and associated loss of land and shorefront properties (USAID, 2008). The mining sector, to be climate-change smart, is important because, a) the critical inputs like energy and water can be easily affected by climate change, b) employees health can be at risk due to disease like malaria and extreme weathers, c) climate change exacerbated vulnerability will bring the mining sector in conflict with the local communities due to competition for resources such as water, d) increased risk will bring project financing to be less secured, and e) climate change will also cause physical damage on mining and communication infrastructure

useful for transporting input to the mining plant and the products of the mining industry to the market.

1.5 Process and results of sector selection

Liberia as a new TNA stakeholder, followed the multi-stakeholder process to select priority sectors for both mitigation and adaptation (see List of Stakeholders in annex III). The process started with approval of the National TNA committee, mapping of stakeholders followed by a national stakeholder validation at the TNA inception workshop in Monrovia. The sector prioritization process considered making presentations of climate change and its impacts, the TNA project and what it means to be a TNA stakeholder. This aspect of the inception workshop provided information to stakeholders so that they could make informed decisions with respect to sector prioritization and technologies. In the end, the stakeholders agreed that the sectors and technologies to be prioritized should be based on the following;

- Current mitigation and adaptation needs;
- Government support in technology rollout;
- There should be piloting of technologies since the country has not done much with the application of modern technologies across various sectors;
- That sectors to be prioritized should have some ongoing activities that the TNA project will compliment;
- Sectors for mitigation should be those that account for most of the national GHG emissions; and
- Sectors for adaptation should be those that are most vulnerable to the impacts of climate change.

Results of Sector Selection

Based on the above analysis and criteria for prioritization, two sectors had been selected for adaptation and one sector for mitigation. The sectors selected are critical for Liberia's growth and development in the face of climate change and other stressors. The priority adaptation and mitigation sectors retained for Liberia include:

1. Priority adaptation sectors: Agriculture and Coastal Zone
2. Priority mitigation sector: Energy sector

Adaptation Options for the Agriculture Sector

Liberia generally has a climate favourable to farming, vast forests, and an abundance of water. However, climate change is affecting food production and increasing food insecurity (EPA, 2018). Based on past and current climate change assessments, there are a number of document that have provided adaptation measures for the agriculture sector, Table 1 below shows a list of documents and adaptation options for the agriculture;

Table 1; Adaptation options proposed from national documents and reports

National documents/Reports	Proposed Adaptation Options
Agenda for Transformation (2012)	• Develop more competitive, efficient, and sustainable food and agriculture value chains and linkages to markets," • Improve food security and nutrition, especially for vulnerable groups such as pregnant and lactating women and children under five, • Strengthen human and institutional capacities to improve needed services, create strong enabling environment, and reduce vulnerability.
INDC (2012)	• Agriculture- Enhancing resilience to increasing rainfall variability through the diversification of crop cultivation and small ruminants rearing; b) • Building of a national hydro-meteorological monitoring system and improved networking for the measurement of climatic parameters; • Building of coastal defence walls to reduce the vulnerability of urban coastal areas.
	• Improve the effectiveness of pest, disease and weed management practices through the wider use of integrated pest and pathogen management, development, and the use of varieties and species resistant to pests and diseases, and improving quarantine capabilities and monitoring programs.

National Policy and Respond Strategy to Climate Change (2018)	• Assess crops vulnerability and suitability (cropping pattern) for different Agro-ecological zones. • Enhance climate proof agro-infrastructural systems (input, output, marketing, post- harvest technologies and infrastructure including storage) that strengthen the capacity of farmers to increase resilience and productivity. • Build and strengthen the capacity of extension officers in new sustainable farming and livestock raising technologies, in order to enhance their support for farmers. • Support communities in livestock and crop sectors through inventory and dissemination of indigenous knowledge, establishing and/or strengthening insurance scheme, early warning and early action system, vaccination campaign, disease control, etc., to cope with the stress based on climate variability. Set up seed banks to collect different varieties of crops in order to preserve local diversity and provide farmers with the opportunity of making informed choices based on suitability. • Develop and introduce a diverse range of integrated soil fertility management (IFSM) techniques to farmers as a sustainable means of improving soil fertility, and intensifying agricultural production. • Promote wider use of appropriate technologies and work with communities to harvest water and discourage the burning of organic residues on the soil surface, in order to prevent soil erosion, water logging and nutrients leaching in increased rainfall scenarios; and to preserve soil moisture in drier rainfall scenarios. • Support farmers to diversify their income through integrating farming activities with other income generation activities such as sustainable livestock rising, bee harvesting, rabbit, poultry, guinea fowl, etc.

	• Encourage farmers to engage adaptation measures as well as coping strategies such as intercropping, irrigation, aquaculture, and the use of climate resilient plant varieties so as to create resilience to the shocks of climate change. • Ensure technologies and methodologies promoted to farmers through agricultural programs are cognizant of different socio-economic levels (e.g., pro-poor) and are gender sensitive.
National Climate Vulnerability and Risk Assessment Report for the Agriculture, Fisheries, and Agriculture sectors (2019	• Promote sustainable water and soil management • Integrated Pest management • Promote farmers field school and develop appropriate extension systems and farmer-to-farmer learning. • Use of improved technologies and adapted seeds and crop and livestock varieties • Promote marketing and climate resilient value chains for rice, cassava, maize, vegetables and livestock products. • Mainstream gender into all farming and livestock activities • Support communities in livestock and crop sectors through inventory and dissemination of indigenous knowledge, establishing and/or strengthening insurance scheme, early warning and early action system, vaccination campaign, disease control, etc., to cope with the stress based on climate variability • Adjustment in commodity and trade policy • Provide financial incentives for the development of value addition of rice, cassava, vegetables, other food crops and livestock. • Build and strengthen the capacity of extension officers in new sustainable farming and livestock raising technologies, in order to enhance their support for farmers.

CHAPTER TWO: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDERS INVOLVEMENT

2.1 Institutional arrangement for the TNA

The National Climate Change Steering Committee (NCCSC) has overall responsibility for climate change policy in Liberia (Republic of Liberia, 2018). The National Climate Change Secretariat (NCCS) is housed in the EPA and it is responsible for carrying out and coordinating the daily operations of the NCCSC. The Environmental Protection Agency (EPA) of Liberia which is the Designated National Authority (DNA) for the UNFCCC and the Kyoto Protocol coordinates, along with other ministries and agencies, the full implementation of major activities under the policy. The EPA is the lead agency responsible for the TNA process in Liberia. It spearheaded the launch of the TNA project on October 23 to 26, 2018 in the presence of representatives from the UNEP DTU Partnership (UDP) and the Regional Centre (Energy Research Centre, University of Cape Town) in Monrovia, Liberia. The following sections outline Liberia's institutional arrangement for the implementation of the TNA project and the stakeholder involvement process which followed the guidebook provided by UNEP-DTU Partnership for countries conducting TNA.

2.2 National TNA team

Figure 2.1 shows the institutional arrangements adopted from the UNEP DTU Partnership TNA guidebook *(TNA Step by Step – A guidebook for countries conducting a Technology Needs Assessment and Action Plan)* to manage the TNA project in Liberia (Haselip *et al*., 2019). Liberia's national TNA team comprised of the core group of persons engaged in the TNA project and it includes the NCSSC, the National TNA Coordinator, the National Consultants for Mitigation and Adaptation, and three (3) Sectorial Working Groups (SWGs) (one for mitigation and two for adaptation).The organisational structure of the TNA project for Liberia is shown in Figure 1. It consists mainly of the National TNA Team and consultants, with the flow of resources and outputs as indicated by the arrows defined in the legend.

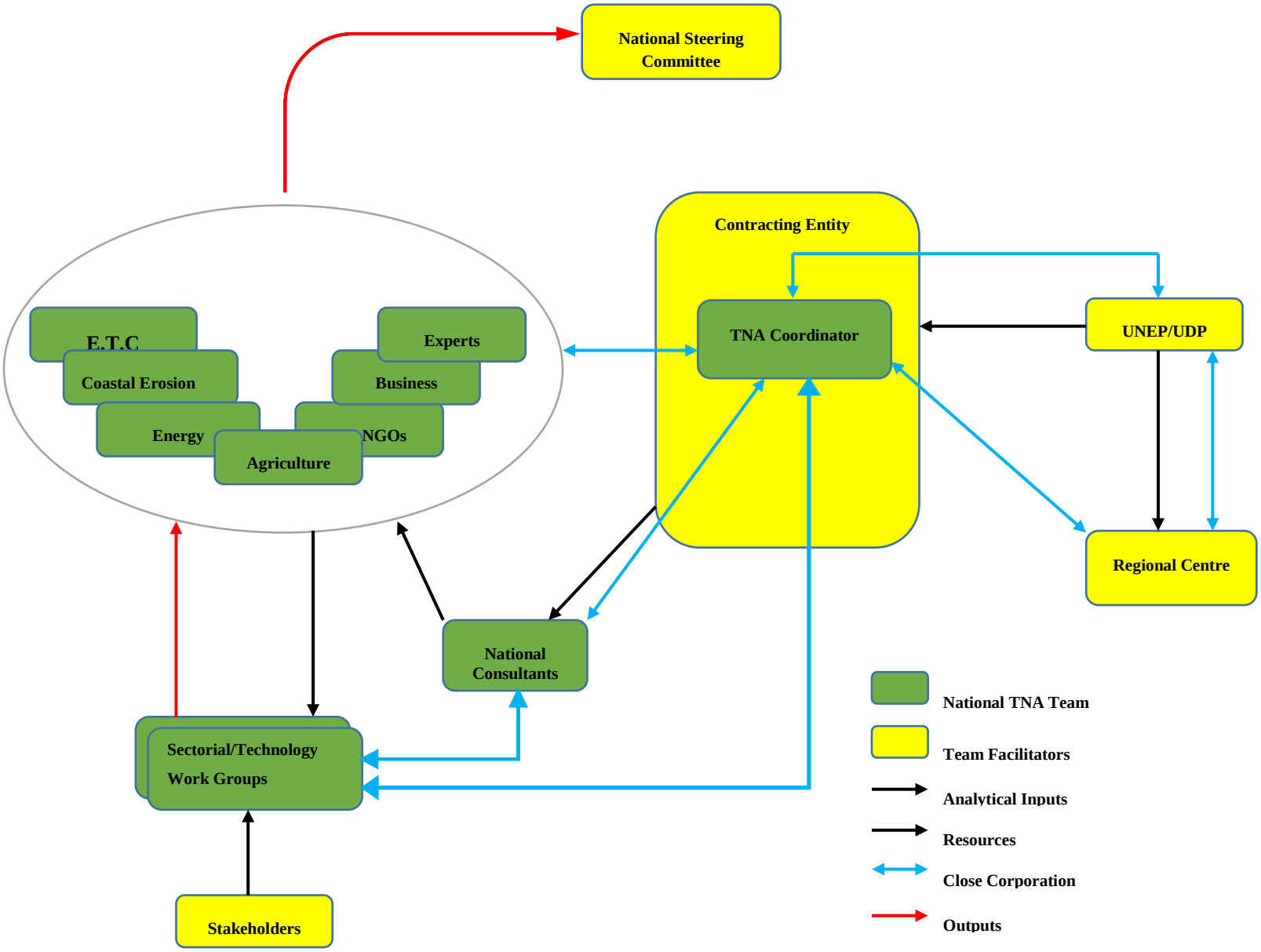

Figure 1: Organizational structure for a TNA process

The National Climate Change Steering Committee (NCCSC)

The NCCSC is the high-level policy coordination body for the overall climate change activities in Liberia. It was established in 2010 by the President of the Republic of Liberia. It comprises of the President of Liberia, Ministers of Government, Directors of Governmental Agencies, National Energy and Climate Change Advisers to the President, private sector, civil society and international partners (Republic of Liberia, 2018). The NCCSC is expected to provide guidance and leadership to the TNA project. The principal role of the NCCSC is to provide high-level guidance to the national TNA team and help secure political acceptance for the Technology Action Plan (TAP). Table 2.1 shows the current and proposed composition of the NCCSC.

Table 2.1: Current and Proposed Composition of the NCCSC (Republic of Liberia, 2018)

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

The National TNA Coordinator

The appointment of the National TNA Coordinator was done by the Environmental Protection Agency of the Republic of Liberia. The TNA Coordinator is the focal point for the effort and management of the overall TNA process. This involves providing guidance, leadership and vision for the overall TNA process; facilitating communication tasks among the National TNA Committee members, National Consultants and stakeholders groups, forming networks, information acquisition, and the coordination and communication of all work products; providing guidance and support for the successful implementation of the TNA project according to the agreed Work Plan; and serving as the official contact point for the country, communicating progress and/or any queries directly with the Country Coordinators at UNEP DTU Partnership and the Regional Centres.

The National Adaptation Consultants

The National Adaptation Consultants work in close collaboration with the National TNA Committee and the adaptation sectorial groups (Agriculture Coastal zone sectors), and is directly responsible to report to the TNA Coordinator. The National adaptation Consultants overall task is to support the entire TNA process.

However the specific responsibilities of the National Adaptation Consultant for the agriculture sector include:

- organizing consultative stakeholder meetings;
- providing support to identify and prioritize adaptation technologies for Liberia's agriculture sector through a participatory process with the broad involvement of relevant stakeholders;
- leading the process of analysing, along with the adaptation stakeholder group, how the prioritized technologies can be implemented in Liberia and how implementation conditions can be improved by addressing the barriers and developing an enabling framework based, inter alia, on undertaking local market and other assessments, as may be required;
- preparing deliverables, including the TNA, BAEF and TAP reports for Liberia's agriculture sector ;
- preparing working papers and other TNA-related documents as may be required to ease the consultative process;
- harnessing inputs from stakeholders during meetings and workshops, among others;
- participate in capacity-building workshops;

- Work in close partnership with the National Coordinator to facilitate communication within the national TNA Team (coordinator, consultants, and sectorial working groups), engage with stakeholders, form networks, and coordinate and communicate all deliverables.

Sectorial Working Groups

The stakeholders are essential to the TNA process. The Sectorial Working Groups (SWGs) are intended to allow stakeholders to play an active role in the TNA. The adaptation Sectorial Working Group (ASWG) consist of stakeholders who contribute their technical expertise and input into technology prioritization, their ideas and inputs for the enabling framework for the Agriculture sector. The following institutions and organizations represented on the MSWG are shown in Table 2.2.

Table 2.2 Institutions and organizations represented on mitigation sectorial working group

Agriculture Working Group
1. Environmental Protection Agency (EPA)
2. Ministry of Agriculture (MoA)
3. Society for the Conservation of Nature (SCNL)
4. National Rice Federation of Liberia (NRFL)
5. National Cassava Sector Coordinating Committee
6. University of Liberia (Agriculture and General Forestry College)
7. Cuttington University (CU)
8. Minister of Gender and Development
9. General Service Agency (GSA)

Note: All of these institutions were mapped during the stakeholder consultative meeting held at the Environmental Protection Agency of Liberia prior to the launch of Liberia's TNA project in Monrovia. Please see Annex III for the list of participants from the prioritization workshop.

2.4 Consideration of Gender Aspects in the TNA process

Gender considerations in all developmental endeavors; and at all levels of the society are important in reducing existing disparity and bridge the gaps to ensure equality for all. TNA process has adopted "gender-sensitive vulnerability and risk assessment". This will be achieved through the consideration of gender during the planning and implementation; with specific focus

on identifying and addressing capacities and access to resources. From the inception of Liberia's TNA project, gender concerns are taken seriously and have since considered participation of male and female in all TNA activities such as stakeholder meetings, workshops among others. There is a 40% - 60% gender participation; 40% women and 60% men participations in the stakeholder working group in the Agriculture sector.

CHAPTER THREE: TECHNOLOGY PRIORITISATION AGRICULTURE SECTOR

Climate change remains a major challenge to Liberia's agriculture sector (EPA, 2019). Based on the current findings of the Climate Vulnerability and Risk Assessment in the Agriculture, Fisheries and Forestry sectors report (EPA, 2019), the agriculture sector remains and will still be vulnerable to climate change based on past, present and future predictions. From this background, five (5) technologies were initially listed based on experts opinions and five Factsheets were prepared for the five technologies. During the workshop two (2) technologies were suggested by the participants making the list of 7 adaptation technologies identified to improve the resilience of the agriculture sector and livelihoods of poor farmer especially rural farmers. Interestingly, the two technologies that were suggested by the stakeholders were all prioritized. However, it is important to note that of the 7 technologies, Liberia will use the first top 3 priority technologies for her TNA project.

The technologies prioritized will benefit both the farmers and traders of agricultural products and improve soil quality and maintenance of local biodiversity and forest resources were integrated. The technology identification exercise drew from multiple sources and the socio-cultural context, including (1) adaptation technologies proposed in previous national documents;(2) technologies currently in practice and supported by national agricultural policy; (3) most needed technologies in the local context (especially grain storage); and (4) easy to be used.

3.1 Key Climate Change Vulnerabilities in the Agriculture Sector

This section provides an overview of the vulnerability of Liberia's agriculture sector to climate change and the main focus area of analysis in TNA. Liberia has not fully adopted technologies in its agriculture sector. Therefore, making anaylsis of the main focus area in TNA will be based on the technologies prioritized by the stakeholders for the agriculture sector of Liberia.

Liberia's total land area is about 111,370 square killometers, with 96,320 square kilometers of land (9.63 million hectares) and 15,050 square kilometers of water. According to LISGIS estimates in 2011, agriculture occupied about 28.1%, arable land 5.2%, permanet crops 2.1%, pasture 20.8%. According to MOA (2009), the principal food crops of Liberia are rice and cassava. Other agricultural grown for commercial purposes include plantations of rubber, palm oil, coffee, cocoa, and sugarcane (MOA, 2009). Crops grown for local consumption include

banana, plantain, citrus, pineapple, sweet potatoes, maize, and vegetables. Rice, cassava and vegetables production account for about 87% of cultivated land in Liberia (MOA, 2009). Liberia agricultre is mostly rain-fed. Most farmers operate at subsistence level on small family plots growing rice, cassava, pepper, bitter balls, greens, aubergines, okra, pulses and corn.

Liberia has two seasons; dry and rainy seasons. The rainy season begins in April and ends in October, while the dry season is from November to March (Wiles, 2005). Liberia is faced climate change and this is impacting the agriculture sector. The EPA (2019) report reveals that warmer temperatures which have led to a reduction in chill hours potentially reducing yields for some crops like maize, rice, rubber, and cassava. It was also reported that for every $1^{o}C$ increase above $30^{o}C$ temperature per day during maize growing season, there is a corresponding 1% reduction in yield each day under optimal rain fed condition (ACPC, 2014). The irrigation potential in Liberia is estimated at 600, 000 ha, consisting mainly of freshwater swamps. However, there is no up-to date information on irrigated areas in Liberia available. Nonetheless, data obtained shows full or partial control irrigation equipped area of 100 ha in 1987, equipped lowlands (wetlands, fllod plains, mangroves) of 2000 ha in 1987 and a non-equipped cultivated wetlands and inland valley bottoms of 18, 000 ha in 1986. The total water withdraw in 2000 was estimated at 106.8 million m^3 (USAID 2015). Agriculture used about 60 million m^3/year (57 percent), followed by the domestic sector with 30.4 million m^3 /year (28 percent) and industry with 16.4 million m^3 /year 15% (USAID 2015). Liberia shares rivers with all its neighboring countries: the Mano and Mugowi Rivers with Sierra Leone; the Makone, Lofa, Via, Nianda and Mani Rivers with Guinea; the Cavalla River with Côte d'Ivoire, (which forms a large part of the border between the two countries).

The agriculture sector contributed about 38.8% of GDP in 2015, employing more than 70 percent of rural households involved in the sector and contributing 23.9% to the real GDP (EPA 2018, USAID 2015). However, the outbreak of the Ebola Virus Disease (EVD) in 2014 temporarily stifled this growth and was followed by the global recession that the country is yet to recover from. Before the 14 years of civil conflicts that started in 1990 to 2003, agriculture accounted for about 40% of GDP and Liberia was a producer and exporter of basic products-primarily raw timber and rubber. The rubber industry generated over US$100 million export earnings yearly.

In 2000, agriculture and forestry contributed over 90% of export earnings, mainly from rubber, timber, cocoa and coffee. Agricultural activities locally are still considerably reduced and the country relies on importation of it staple food (rice) mainly from China and India. Rice production in 1995 was only 23% of the pre-civil war level (MOA, 2009). Cassava production has also been falling, possibly by as much as 50%. Low productivity of land and labour, shifting cultivation and low livestock production remain the main characteristics of traditional farming in Liberia. Rain fed agriculture is the predominant system. Use of water control technology is exceptional and consists mainly of unregulated manual irrigation, using watering cans. Liberia is far from being food self-sufficient. Other constraints in the agricultural sector are relate to low levels of productivity, inadequate irrigation and inputs of fertilizer, poor quality of seeds and breeding stock, lack of credit, machinery and infrastructure for transport, storage and marketing.

Current Vulnerabilities in the Agriculture sector

Liberia has a rain-fed agriculture system. Climate change has posed serious challenge on all sectors and has adversely threatened sustainable agricultural production in Liberia. Recent data obtained by the EPA shows that warmer temperatures are affecting food crops production and impacting livestock making farmers to complain about the fluctuation in rain patterns (EPA, 2019). Observations have shown that May and June are wetter than expected and this has implications for farm productivity. May and June are predominant planting periods for farmers especially those engaged in upland agriculture in Liberia. Excessive rain during this time of the year washes away plant seeds and sprouting plants thereby causing low productivity (EPA, 2019).

Climate Change Projections and Impacts

Climate change is already been felt in the agriculture sector of Liberia. The historical climate change scenarios include increased average annual temperatures of 0.8°C throughout the country, a 15.7% increase of hot nights, decline in mean annual rainfall, increased frequency and unpredictability of intense rainfall events and rising sea-level. These scenarios are projected to 0.9°–2.6°C increase in temperature by 2060 (USAID, 2012), substantial increase in the frequency of “hot” days and nights, increase in frequency and intensity of extreme weather

events by 2050 and 0.13–0.56 m increase in sea levels by 2100. In addition, it is projected that by 2100 sea level will rise between 0.13-0.56m in the country (USAID, 2017).

Predictions show that there will be changes in temperature by 2050 and 2080 for Monrovia, Nimba, and Sapo National Park are based on a 16 models (Stanturf, et al., 2013). The general trends are for a warmer climate in most of the country. The most conservative estimates on temperature change have Monrovia warming by an estimated average of 1.54°C by 2050 and 1.90°C by 2080 during the dry season (1.30°C by 2050 and 1.85°C by 2080 for the wet season). In the interior, Nimba is estimated to warm by an average of 1.50°C by 2050 and 2.13°C by 2080 during the dry season (1.38°C by 2050 and 1.82°C by 2080 for the wet season). In the southeast, Sapo National Park is projected to warm slightly less, by an estimated average of 1.44°C by 2050 and 1.95°C by 2080 during the dry season (1.29°C by 2050 and 1.73°C by 2080 for the wet season. Pprediction on precipitation across Monrovia emission scenarios gives a slight increase in wet season with rainfall of 1.54 ± 11.09% by 2050 and 1.92 ± 13.21% by 2080. The overall ensemble prediction at Sapo National Park across emission scenarios gives a slight increase in wet season rainfall of 3.54 ± 11.55% by 2050 and 5.25 ± 16.26% by 2080 (McSweeney et al., 2008). The overall ensemble prediction in Liberia across emission scenarios gives a negligible change in wet season rainfall of 0.35 ± 10.28% by 2050 and 0.40 ± 13.67% by 2080 (McSweeney et al., 2008).

3.3 Decision context

Liberia has taken key steps in the agriculture sector to attain growth and development in the face of climate change and other natural challenges. Some current initiatives in the Agriculture sector gear towards adapting to climate change vulnerabilities include the followings;

- Liberia Agricultural Sector Investment Plan. (LASIP) I: 2011 - 2015 and LASIP II: 2018 – 2022. LASIP will be a public-private partnership (PPPs) in which investment growth for the export sectors will be spearheaded by the private sector, while the public sector will concentrate in promoting small farmer growth and development.
- Commercial Farming Project in Foyah Lofa County.
- West Africa Agricultural Productivity Project (WAAPP-Liberia)—a regional project supported by the World Bank and Japanese Government—has helped fund the

resuscitation of the Central Agricultural Research Institute (CARI), Liberia's only agricultural research institute, which was badly damaged during the country's civil wars. WAAPP supported 32 young Liberian scientists, some of whom earned Masters' degrees or PhDs at African universities, and all of whom completed their studies. Now they serve in Liberia's Ministry of Agriculture and at CARI.

- The Smallholder Agricultural Productivity Enhancement and Commercialization (SAPEC) Project is a $52M project that seeks to reduce rural poverty and household food insecurity by increasing income for smallholder farmers and rural entrepreneurs particularly women, youths and the physically-challenged.
- Smallholder Agriculture Transformation and Agribusiness Revitalization Project (STAR-P) of Liberia. A 25 million $ project funded by the World Bank.
- Liberia Agribusiness Development Activity 2015-2020 (LADA), an initiative by USAID's Feed-the-Future programme. Started in December 2015, LADA aims to increase incomes of smallholder farmers and entrepreneurs throughout Liberia. The project aims to expanded access to and use of agricultural inputs, improved post-harvest activities, and streamlined high-potential agricultural value chains.

Regulatory Framework in the Agriculture Sector

- **Liberia Food and Agriculture Policy Strategies (FAPS) 2008*:*** FAPS seeks to address the plethora of problems that have historically bedeviled agriculture and its linkages to the other sectors in a coherent, consistent and forward-looking manner. FAPS articulate three fundamental orientations related to improving national food and nutrition security, enhancing agricultural productivity, competitiveness and linkages to market and finally to strengthening human and institutional capacities.
- **Liberia's National Rice Development Strategies (LNRDS) 2012.** The LNRDS aims to achieve self-sufficiency by doubling the local rice production by the year 2018. The strategies proposed here aim to achieve this by increasing the rice productivity in both upland and lowland ecosystems and by expanding the land area under rice cultivation in the lowlands.
- **Liberia National Livestock Policy and Veterinary and Animal Law 2014 (draft)***:* The following options were advocated: (i) provide credible and improved public and private

veterinary services; (iii) provide disease diagnostic and investigation facilities; (ii) develop research capacities; (iii) delivery of technology; (iv) promote data collection and analysis (v) strengthen marketing of animal product; (vi) regulate import and export of animals and their products (vii) promote animal welfare; (viii) promote use of environmentally friendly technologies; (ix) promote sustainable livestock production; (x) promote equal access to resources and credit for livestock production, processing and marketing; (xi) improve capability of the livestock subsector in providing affordable animal products and (xii) expand livestock enterprises.

- **The Liberia Agricultural Transformation Agenda:** LATA aims to enable Liberia to achieve higher levels of economic resilience through inclusive growth and four guiding principles: developing agricultural value chains, adopting innovative finance solutions, promoting an export-driven industrial policy and ensuring an enabling business environment. The value chains selected are oil palm, rubber, cacao, fisheries, rice, cassava, horticulture and poultry/livestock. The government is seeking strategic investors in agriculture, agro-processing and manufacturing as well as explores possibilities of Public Private Partnerships.
- **Liberia National Cassava Sector strategy (NCSS) 2008**. NCSS is an agreed long-term plan of action by Liberian cassava sector stakeholders and the Government of the Republic of Liberia, for the development of the nation's cassava sector. It identifies and articulates specific time bound actions and measures to enable the sector to reach its full potential through a coordinated approach that involves all sector stakeholders.
- **Cooperative Development Agency (CDA):** The Cooperative Development Agency is the main instrument of the government through which support is provided to cooperatives in the country. The civil war mostly destroyed the CDA infrastructure, but work has resumed on rebuilding the infrastructure and other capacities to pre-war levels. CDA is active in the main cocoa producing counties of Bong, Nimba and Lofa.
- **Liberia Cooperative Development ACT of 2010 and Regulation of 2010**: These documents were developed to inform the growth of the agricultural sector. They provide an enabling institutional and legal environment for the development of autonomous, viable and demand driven cooperative organizations.
- **National Export strategy:** Together with the International Trade Centre (ITC) Liberia developed this strategy in April ofq 2014 to democratize the export culture by incorporating

Micro, Small and Medium Enterprises (MSME). These enterprises have historically been neglected as Liberia's economic growth was fueled by commodity and extractive sectors which were primarily concessionaire-based activities.

- **Liberia Agriculture Commodity Regulatory Authority (LACRA)***:* The LACRA Act was passed in 2016 under the LATA. It has been set up to develop functioning value chains and market systems and is an effective regulatory system for the trading of agricultural commodities. It protects value chains from under investment and poor crop quality. Its focus is the cacao sector, one which is critically constrained by side-selling, but has the mandate to cover other commodities such as coffee as well.

Future initiative in the Agriculture Sector

From the EPA's Climate Change Vulnerability and Risk Assessment in the Agriculture, Fisheries, and Forestry sectors report of 2019, the country has identified key adaptation measures that will focus on the most vulnerable people and communities, health and well-being, and food and water security, and Ecosystems and ecosystem services through implementing climate-smart agriculture in Liberia. The country planned to seek funding of 25 million USD from the Green Climate Fund under the National Adaptation Programs (NAPs).

3.4 Overview of Existing Technologies in the Agriculture Sector

The Agriculture sector of Liberia has long since depended on traditional practices such as shifting cultivation (slash and burn) and had not fully used technologies to improve the sector. Information about technologies employed in the sector is not available. However, the irrigation potential is estimated at about 600,000 hectares (ha) but only about 1,000 ha can be described as a surface irrigation facility. The total water-managed area in 1987, including rice swamp control, was estimated at about 20,100 ha (FAO, 2005). These areas include equipped lowlands (2,000 ha) and non-equipped cultivated swamps (18,000 ha). Irrigation infrastructure is virtually non-existent because of abundant water resources in the country. Water control structures for swamp rice production are extensive (although they are likely to be significantly degraded). Areas with good water control and having the possibility of two crops per year are limited. There are also peri - urban irrigation activities around Monrovia but the method of irrigation is predominantly by hand. There is no shortage of water resources for agricultural development. Assuming that the water requirement of the staple rice crop is 1,500 mm, considering losses through surface

evaporation, drainage etc., and the total land area of about 400,000 ha of both upland and swamp rice, which is projected to be required to achieve rice self-sufficiency, this will require an annual renewable water supply of approximately 6 billion m^3 or 6 km^3/year. This is only about 2.6% of the total annual renewable water resource of 232 km^3/year (MOA, 2009).

Achieving the full irrigation potential of the country will require a more integrated land and water approach to address the prevailing constraints. Liberia does not have a comprehensive policy document that addresses water development of water resources, possessing only dislocated pieces of legislation on land, mining, forestry and water supply that relate to water resources. Basic water management data for crops are not available and research in Liberia does not seem to consider this to be a priority, probably because of the abundance of water resources. Upland water management and water management on slopes are not considered critical issues in the farming community. The upland soils are generally acidic, with low fertility, low water-holding capacity, and are prone to soil erosion, yet soil, and water management is not much of an issue for the farmers. Even though there are limited data to support the claim, current land use practices are deemed to be having an effect on water resources, as suggested by the seasonality of some tributaries that used to be perennial, and changing rainfall patterns. Forest cover is being reduced due to current farming practices, thus posing a threat to soil fertility, biodiversity and the water resources of the nation.

Given the limitations of the agriculture sector in terms of technologies, it will require serious investment to achieve the TNA project goal and objectives in Liberia.

3.5 Adaptation Technology Options for the Agriculture Sector and Their Main Adaptation benefits

List of technologies options for the agriculture sector

1. Mixed farming
2. Crop Diversification
3. Improved Storage (drying and freezing of agriculture products)
4. Irrigation
5. Value Addition
6. Ecological pest management
7. Seed and grain storage

3.6 Criteria and Process of Technology Prioritization

Two steps were used to arrive at a shortlist of technology options for adaptation in the agriculture sector. The first step consisted of pre-screening most likely implementable adaptation technologies from the long-list of identified technologies. The pre-screening was done considering 1). Liberia's current climate vulnerability and risks in the agriculture sector, 2). The proposed technological needs from the National Policy Response Strategy on climate change of 2018, and 3) Based on the view and opinion of participants in the workshop; the second step consisted of developing technology factsheet (TFS) for each of the short-listed technologies, and establishing the criteria and indicators for technology prioritization using MCA. The list of Factsheets can be seen in Annex 2.

3.7 Results of Technology Prioritization

The TFS were circulated to all members of the technical working group for familiarization with the technology options prior to the MCA prioritization exercise, which involved scoring, weighting. The MCA calculator used for technology prioritization in agriculture is shown at Annex 3. The calculator also contains the methodologies and calculations used to estimate the incremental cost of adaptation technologies.

Scoring: A performance score card in which each row describes a technology option and each column describes the performance score of the options against each criterion was developed and filled following thoroughly discussion with technical working team during the prioritization workshop. The scoring matrix for each criterion scores was from 0 to 100. The working group agreed that 0 was the least score and 100 were the highest score.

Weighting*:* Expert judgements were sought from members of the agriculture technical working group to assign a numerical weight (between 0 and 10) to each indicator to reflect their relative importance in the decision making process. The cumulative sum of weights across all indicators was equal to 100. In order to minimize bias, weights were assigned to indicators prior to scoring the technologies.

Combining weights and scores*:* The linear additive model was used to derive the total weighted score of each technology option. This was done for a technology by multiplying its score for each criterion by the corresponding weight of that criterion, and then adding the weighted scores

to give the total weighted score for this technology. The 7 adaptation technologies were then ranked according to overall preference. The option scoring the highest total weighted score was rank as the most preferred options, whereas the one with the lowest score was ranked as the least preferred option. Please see below table 2 showing the ranking of adaptation technologies in the agriculture sector. There was no sensitivity analysis carried out during the prioritization of adaptation technologies for the agriculture sector.

Table 2: Ranking of Adaptation Technologies in the Agriculture Sector

Rank	Technology
1	Value addition to agriculture products
2	Improve storage (drying and freezing of agriculture products)
3	Integrated Soil Fertility Management
4	Crop Diversification and new varieties
5	Irrigation
6	Ecological pest management
7	Mixed farming

CHAPTER FOUR: SUMMARY AND CONCLUSIONS

4.1 Summary

The Technology Needs Assessment process for adaptation in the agriculture sector for Liberia was carried out with the involvement of the relevant stakeholders. The identification and prioritization of technological options was done using the multi-criteria analysis. National stakeholders through a series of brainstorming forums identified the indicators that were eventually used.

During the elaboration of the TNA, several data sets were accessed and compiled, and complemented with desk review, including review of existing national policies specific to technological innovation, adaptation to climate change was; vulnerability assessment in the country; key climate change vulnerabilities in the agriculture sector; and stakeholders engagement with high level of gender consideration.

4.2 Conclusions

The Technology Needs Assessment for the Agriculture sector was conducted with the involvement of multi-stakeholders. The Environmental Protection Agency of Liberia took the lead. A national consultant was recruited. A number of meetings and stakeholders' engagement forums held. Several technical investigations were carried out, including vulnerability assessments in the country; overview of expected climate change and its impacts in sectors vulnerable to climate change; key climate change vulnerabilities in the Agriculture Sector; and existing national policies related to technological innovation, adaptation to climate change and development priorities.

To support the stakeholders' engagement process, key stakeholders were identified; and they include representatives from government ministries, agencies and commissions, academia, research institutions, local government authorities, private sector, civil society and non-governmental organizations, the media and Liberia development partners.

Three technologies were prioritized for the agriculture sector and they include; Value Addition technology, Integrated Soil Fertility management technology, and Storage technology but they are relatively new to the country, and have not been tested. However, the stakeholders are of the conviction that investments in the prioritized technologies will see a resilient agriculture sector in Liberia.

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ANNEX

Annex 1 a; **Technology Factsheets for selected Technologies**

SECTOR	AGRICULTURE
CATEGORY	Irrigation Application, Supply – side
ADAPTATION NEEDS	• Guarantees yields of agricultural crops in an increasingly dry climate especially in the northern region of Liberia. • Reducing of water and energy consumption for irrigation needs in agriculture
TECHNOLOGY NAME	Low pressure and water serving Sprinkler Irrigation technologies
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	• Irrigation serves as an important tool for ensuring yields in conditions increasingly dry climate of Liberia when lack of natural moisture of the soil will only grow in the future. • Irrigation is the most climate-sensitive use of water. The yields and profitability of irrigated land relative to dryland farming tend to increase as conditions become hotter and drier. Currently, due to the change in farming calendar in Liberia as a result of prolong sunshine, most famers are moving to lowland as was reported (EPA, 2019). • In these conditions, to reduce consumption of energy and water for irrigation is a major challenge to adapt to climate change.
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	• At sprinkling irrigation, water on the field is usually served on pressurized pipelines, and then sprayed it in the form of artificial rain over the irrigated area by sprinkling machines and installations. The principles of creating energy and resource-saving irrigation systems. • Application of low-flow (local) irrigation methods to reduce the irrigation water consumption; • Eliminating losses of irrigation water from irrigation canals and pipelines and its flow into the groundwater; • Minimization of the impact of irrigation on soil through the use of irrigation regime based on the principle of additional moisture to natural rainfall; • Using of information-measuring systems for: -continuous recording and processing of agro-meteorological data on irrigation site: air temperature, relative humidity, rainfall, wind speed and direction, solar radiation, ultraviolet radiation, evapotranspiration, irrigation terms and forecast weather conditions; -continuous monitoring of the soil moisture movement; • Using of alternative energy sources for water supply: solar energy, wind energy, gravitational energy of the water in case the water source located higher on irrigated area. Introduce Sprinkler Systems and Practices in Liberia.
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	This technology is not widely used by many farmers in Liberia. Besides, the country is still short on energy supplies to most rural counties. However, introducing this technology to rural farmers will require the supply of solar energy hand-in-hand. This can be achieved if there is adequate budgetary allocation to projects that will stimulate farmers to use advanced resource-saving irrigation systems. Access to low interest loan will increase farmer's capacities to acquire modern irrigation systems and promote their sustainable use.
COST	Center pivot sprinkler irrigation system - US$ 3,564

COUNTRY SOCIAL DEVELOPMENT PRIORITIES	Liberia social development agenda lies in the followings; Pro-Poor Agenda for Prosperity and Development 2018 to 2023 (PAPD), National Energy Policy of Liberia, Liberia Food and Agriculture Policy Strategies (FAPS) 2008, The Liberia Agricultural Transformation Agenda, Liberia Agriculture Sector Investment Program (LASIP- 2009), National Policy and Response Strategy on Climate Change of 2018, Integrated Water Resources Management Policy (IWRMP 2009), Climate Change Vulnerability and Risk Assessment in the Agriculture, Forestry, and Fisheries Sectors 2019.
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	• High value agricultural development • Impacts on water supply • Improvement of irrigation water consumption
COUNTRY ENVIRONMENTAL DEVELOPMENT PRIORITIES	Reduction of impact to the country environment
SOCIAL BENEFITS	• Increasing of farming population incomes from guaranteed high yields • Educational and scientific development • Increased community welfare • Reduce poverty in rural communities
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	None
CAPITAL COST (PER FACILITY)	132 acres installed at a cost of $48,000 with a power and water source and connecting equipment cost of $30,000
OPERATIONAL AND MAINTENANCE COST (PER FACILITY)	132 ha Lateral-move Irrigation Systems average Operational and Maintenance costs – $15,055 per season (120 working days) • Total Operational and Maintenance costs for 378.787 ha – $5,702, 651.515million
DAILY SUPPLY CAPACITY (PER FACILITY)	Daily productivity – 20 ha
UP-SCALING POTENTIAL	Daily productivity – 30ha

Annex 1 b; Technology Factsheets for selected Technologies

SECTOR	AGRICULTURE
CATEGORY	Lowland and upland farming
ADAPTATION NEEDS	• Climate Change buffering • Pest suppression • Disease suppression • Increased production stability
TECHNOLOGY NAME	Crop Diversification and New varieties
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	Adaptive capacity contributing to improved agricultural productivity at the household level. Guarantees the availability of food crops for poor rural communities.
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	Genetic diversity of rice reduces fungi blast occurrence (Zhu et al., 2000). Grassland or refugia planted at field margins (beetle banks) are used as overwintering habitat for natural enemies (Thomas et al., 1999). Greater shade cover led to increased buffering of crop to temperature and precipitation variation (Lin, 2007). Greater shade cover led to increased buffering from storm events and decreased storm damage (Philpott et al., 2008).
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	Currently, the technology has not been widely applied in our farming system. However, with the involvement of stakeholders from the farming population will help to make it easier for diffusion across the sector.
COST	Implementation and technology application costs The cost of technology is difficult to determine, it depends on the ecological characteristics, natural conditions, socio-economic areas. Incremental costs to adapt to climate change (compared to conventional technology) Crop diversification has higher initial costs compared to normal Insect Pest Management and the efficiency is usually much lower.
COUNTRY SOCIAL DEVELOPMENT PRIORITIES	Pro-Poor Agenda for Prosperity and Development 2018 to 2023 (PAPD), Liberia Food and Agriculture Policy Strategies (FAPS) 2008,

	Climate Change Vulnerability and Risk Assessment in the Agriculture, Forestry, and Fisheries Sectors 2019.
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	Improve farmer's income level and bring about economic stability.
COUNTRY ENVIRONMENTAL DEVELOPMENT PRIORITIES	Preventing pollution by reducing pesticide use; Growing crops and trees together.
SOCIAL BENEFITS	Build capacity of farmers,
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	None
CAPITAL COST (PER FACILITY)	High cost (Potentially high initial cost)
OPERATIONAL AND MAINTENANCE COST (PER FACILITY)	Not Determined
DAILY SUPPLY CAPACITY (PER FACILITY)	
UP-SCALING POTENTIAL	Is not known

Annex 1 c; Technology Factsheets for selected Technologies

SECTOR	AGRICULTURE
CATEGORY	Lowland and Upland farming system
ADAPTATION NEEDS	Guarantees the availability of food crops for rural people.
TECHNOLOGY NAME	Ecological Pest Management
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	Mitigate losses in agricultural crops especially during the dry season. Guarantees the availability of food crops and help farmers save more money.
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	Insect and pest control is an efficient method in agricultural production. However, integrated pest and insect management has not been started in Liberia.
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	Currently, the technology is not being applied in our farming system. However, involvement of stakeholders from the farming population will help to make it easier for diffusion across the sector.
COST	Implementation and technology application costs The cost of technology is difficult to determine, it depends on the ecological characteristics, natural conditions, socio-economic areas. Incremental costs to adapt to climate change (compared to conventional technology) Pest Management Integrated has higher initial costs compared to normal Insect Pest Management and the efficiency is usually much lower.
COUNTRY SOCIAL DEVELOPMENT PRIORITIES	It can be easily used by male or female farmers
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	Improve farmer's income level and bring about economic stability.
COUNTRY ENVIRONMENTAL DEVELOPMENT PRIORITIES	Preventing pollution by reducing pesticide use
SOCIAL BENEFITS	Reducing pest and diseases for crops, thus reducing pesticide costs. Enhancing crop productivity and quality.
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	None

CAPITAL COST (PER FACILITY)	High cost (Potentially high initial cost)
OPERATIONAL AND MAINTENANCE COST (PER FACILITY)	Not Determined
DAILY SUPPLY CAPACITY (PER FACILITY)	
UP-SCALING POTENTIAL	The information is not known

Annex 1 d; Technology Factsheets for selected Technologies

SECTOR	AGRICULTURE
CATEGORY	Seed, Grains and Vegetables Storage
ADAPTATION NEEDS	o Mitigate losses in agricultural crops during the peak of harvest especially during the rainy season o Guarantees the availability and low cost of food crops in all seasons
TECHNOLOGY NAME	Improved Storage
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	o Improved storage is an essential tool that guarantees the availability and low cost of food crops for both the farmer and consumer, o The potential impact on poverty reduction and greater livelihood security will not be realized if farmers are unable to store grain and sell surplus production at attractive prices (Tefera and Abass, 2012). o Increase farmer's ability to increase crop production and improve health of women and income for men and women farmers.
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	Cereals, pepper, potatoes grains, cassava leaves, etc. are very important grains products for storage. Good storage helps ensure household and community food security until the next harvest and commodities for sale can be held back so that farmers can avoid being forced to sell at low prices during the drop in demand that often follows a harvest. While considerable losses can occur in the field, both before and during harvest, the greatest losses usually occur during storage. Therefore the basic objective of good storage is to create environmental conditions that protect the product and maintain its quality and its quantity, thus reducing product loss and financial loss. Only well-dried seeds should be stored. Seeds with moisture in them become damp, moldy and vulnerable to insect attacks.
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	The Ministry of Agriculture will provide training on good harvesting and handling of agricultural products. The Ministry of Commerce through the Standards Division for health and safety should enforce regulations and quality control guidelines, local financial institutions, and donors should provide funds and farmers' corporative who are indeed the first beneficiaries. Health and safety regulations and quality control guidelines should be elaborated by the Environmental Protection Agency (EPA). Standardized training and inspections may also be undertaken by a government The EPA.
COST	To build storage facilities for seed, Grain and Vegetables in the 3 agro-ecological zones of Liberia, it will cost US$5 million
COUNTRY SOCIAL DEVELOPMENT	• Jobs creation will be involved in storage systems installation, operations and maintenance.

PRIORITIES	• Investments opportunities exist in manufacturing and supply of in storage systems components and spare parts. • A lot can be saved on seeds and grain importations.
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	• Existing storage techniques are fragile and not reliable • Improved storage infrastructures are generally absent and yet producers need them • There is a possibility to keep surplus produce stored away rather than having to sell any extra produce immediately • There is a possibility to sell any extra produce • There is increased profit through improved storage • There is storage facility in Grand Cape Mount for the fishery sector currently installed through a World Bank funding which makes available knowledge and skills to implement the new technology • There exist benefits against investment on time, money and effort in improving storage.
COUNTRY ENVIRONMENTAL DEVELOPMENT PRIORITIES	Grain storage has been established to prepare for droughts and hunger and malnutrition (UNEP, 2010). Grain storage provides an adaptation strategy for climate change by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought (UNEP, 2010). Efficient harvesting can reduce post-harvest losses and preserve food quantity, quality and the nutritional value of the product (FAO, 2010). Innovations for addressing climate change include technologies for reducing waste of agricultural produce (BIAC, 2009). In fact, the establishment of safe storage for seeds and reserves of food and agricultural inputs are used as indicators of adaptive capacity in the agriculture sector (CARE, 2010).
SOCIAL BENEFITS	• Through the selling of their products at a reasonable price sometime after harvest time, farmers earn extra income. • With this income farmers can send their children to school. • Well contained and stored grain would protect humans against storage pests such as insects, fungi etc
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	Seed and grain storage systems can be applied from small to large scales. In Liberia, the technology has potential nationwide to bring about agriculture bloom.
CAPITAL COST (PER FACILITY)	The estimated cost per facility is US$1m
OPERATIONAL AND MAINTENANCE COST	It will cost 25,000 USD per annual

(PER FACILITY)	
DAILY SUPPLY CAPACITY (PER FACILITY)	2000ton
UP-SCALING POTENTIAL	2500ton

Annex 1 e; Technology Factsheets for selected Technologies

SECTOR	AGRICULTURE
CATEGORY	On-Farm
ADAPTATION NEEDS	Guarantees greater food security Improved household nutrition level. Generates surplus products that can be sold at market. Diversified income sources More regular income streams
TECHNOLOGY NAME	Mixed Farming
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	Buffer against weather fluctuations; Control erosion by planting forages, Improved nutrient cycling because of direct soil–crop–manure relations, Allow larger areas to be cultivated and more flexible residue management Allow more rapid planting,
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	Mixed farming is a rain-fed and is practice in west, East, and southern Africa (Thornton & Herrero, 2015). Mixed farming system allow intensified farming with less dependence on natural resources and preserving more biodiversity (FAO, 1996). However, mixed farming systems form the backbone of African agriculture and provide most of the staples consumed by many millions of poor people in Africa: between 41 and 86% of the maize, rice, sorghum and millet, and 90% of the milk and 80% of the meat. However, mixed systems could play a critical role in mitigating greenhouse gases from the agriculture, forestry and land-use sectors (Thornton & Herrero, 2015).
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	The Environmental Protection Agency (EPA) in collaboration with the Ministry of Agriculture will raise awareness about the importance of mixed farming to rural population of Liberia.
COST	To estimate the costs of implementing this technology, it will require calculating the cost of wages, agricultural tools, and inputs (seeds and fertilizers). Infrastructure for supporting livestock, cost in crop-animals systems, training and dissemination of this technology.
COUNTRY SOCIAL DEVELOPMENT	Provides security and a means of saving for poor farmers

PRIORITIES	in Liberia; Confers prestige on farmers in Liberia.
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	Increased in national revenue; Jobs creation for mainly women;
COUNTRY ENVIRONMENTAL DEVELOPMENT PRIORITIES	This technology aligns with Liberia's National Environmental Policy of 2003. • It maintains soil fertility by recycling soil nutrients and allowing the introduction and use of rotations between various crops and forage legumes and trees, or for land to remain fallow and grasses and shrubs to become reestablished; • maintain soil biodiversity, minimize soil erosion, help to conserve water and provide suitable habitats for birds; • Make the best use of crop residues. When they are not used as feed, stalks may be incorporated directly into the soil, where, for some time, they act as a nitrogen trap, exacerbating deficiencies. In the tropical semi-arid areas, termite action results in loss of nutrients before the next cropping season. Burning, the other alternative, increases carbon dioxide emissions; and • Allow intensified farming, with less dependence on natural resources and preserving more biodiversity than would be the case if food demands were to be met by crop and livestock activities undertaken in isolation.
SOCIAL BENEFITS	Uncertain
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	None
CAPITAL COST (PER FACILITY)	High cost (Potentially high initial cost)
OPERATIONAL AND MAINTENANCE COST (PER FACILITY)	Not Determined
DAILY SUPPLY CAPACITY (PER FACILITY)	Uncertain
UP-SCALING POTENTIAL	Unknown

Annex 1 f. Technology Factsheets for selected Technologies

SECTOR	AGRICULTURE
CATEGORY	On-Farm
ADAPTATION NEEDS	Guarantees the availability of food crops for rural people.
TECHNOLOGY NAME	Integrated Soil Fertility Management (ISFM)
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	Guarantees the availability of food crops and help farmers save more money.
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	Shifting cultivation (slash and burn) is the traditional farming practice known in Liberia (MOA, 2009). Farmers move from one area of cultivated land to another in search of fertile soil for agricultural production. Liberia has lost 600,000 ha of forested area to shifting cultivation as was reported in 2002 (FAO, 2015). Integrated Soil Fertility Management (ISFM) refers to making the best use of inherent soil nutrient stocks, locally available soil amendments (for instance, crop residues, compost, animal manure, green manure), and inorganic fertilizers to increase productivity while maintaining or enhancing the agricultural resource base (IFDC, 2003).
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	Organic fertilizer is already being introduced by a company called “Organic Matters” and is currently raising awareness and introducing it to local farmers in Liberia. Besides, The Ministry of Agriculture in collaboration withUSAIDlaunched the FOOD AND ENTER PRISE DEVELOPMENT (FED) PROGRAM FOR LIBERIA in 2012. Under this project, they introduced organic fertilizer. The Environmental Protection and the Ministry of Agriculture will work in close collaboration to build upon what this company is already doing.
COST	It will cost US$4 million to continue to establish and run at least 4 facilities in four agro-ecological zones.
COUNTRY SOCIAL DEVELOPMENT PRIORITIES	It can be easily used by male or female farmer.
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	Improve farmer’s income level and bring about economic stability. It helps to reduce the cutting down of forested areas thereby allowing for biodiversity conservation
COUNTRY	• Minimize nutrients losses to the environment;

ENVIRONMENTAL DEVELOPMENT PRIORITIES	• Maximize crop production; • Intensify agricultural production and reduces pressure for the conversion of additional lands.
SOCIAL BENEFITS	Enhancing crop productivity and quality.
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	Already there is a market available and investing in this technology will help improve farmer's ability to purchase cheap available fertilizer.
CAPITAL COST (PER FACILITY)	High cost (Potentially high initial cost)
OPERATIONAL AND MAINTENANCE COST (PER FACILITY)	It will cost US$30,000 per/yr per facility
DAILY SUPPLY CAPACITY (PER FACILITY)	3000ton
UP-SCALING POTENTIAL	3500ton

Annex g. Technology Factsheets for selected Technologies

SECTOR	AGRICULTURE
CATEGORY	Supply side
ADAPTATION NEEDS	Guarantees the availability of food crops all year round especially for rural people.
TECHNOLOGY NAME	Value Addition
HOW THIS TECHNOLOGY CONTRIBUTES TO ADAPTATION	Improves farmers' incomes and savings; Guarantees the availability of food crops and help farmers save more money.
BACKGROUND/NOTES, SHORT DESCRIPTION OF THE TECHNOLOGY OPTION SOURCED FROM	Add value to a product is important for maximizing profit (Lindgreen et al., 2012). Adding value to products gives recipients many choices in selecting products as per their need (Flint et al., 2011).
IMPLEMENTATION ASSUMPTIONS, HOW THE TECHNOLOGY WILL BE IMPLEMENTED AND DIFFUSED ACROSS THE SECTOR?	This technology is somewhat new to Liberia, therefore implementing this technology will require the Environmental Protection Agency of Liberia, the Ministry of Agriculture and the Ministry of Health will have to work hand-in-hand implement this technology.
COST	It will cost an initial investment of US$15 million to establish 3 major facilities for value addition of agricultural products.
COUNTRY SOCIAL DEVELOPMENT PRIORITIES	It can be easily used by male or female farmers and producer of agricultural products.
COUNTRY ECONOMIC DEVELOPMENT PRIORITIES – ECONOMIC BENEFITS	Improve farmer's income level and bring about economic stability.
COUNTRY ENVIRONMENTAL DEVELOPMENT PRIORITIES	Reduce wastage of agricultural products thereby preventing pollution.
SOCIAL BENEFITS	Improve income of producers and sellers of agricultural products.
OTHER CONSIDERATIONS PRIORITIES (SUCH AS MARKET POTENTIAL)	It has a higher market potential as there is a greater need to save time and money.
CAPITAL COST (PER FACILITY)	High cost (Potentially high initial cost)
OPERATIONAL AND MAINTENANCE COST (PER FACILITY)	US$40,000
DAILY SUPPLY CAPACITY (PER FACILITY)	4000ton

UP-SCALING POTENTIAL	4500ton

Annex II: MCA calculator for technology prioritization in Agriculture sector

	Costs		Benefits										
			Economic				Social			Environmental			Climate related
	Capital Cost	Maintenance and operation	Income	Profit	Increase in Livelihood options	Gender	Employement	Education/Training	Poverty reduction pontential	Potential to reduce pensticide	Reduce waste of agricultural produce	Improved environmental sustainability	Resilience to Climate change
Improved Storage	100	70	100	100	100	100	70	50	100	20	100	100	100
Ecological Pest Management	100	40	70	90	60	70	60	100	70	100	100	100	60
Irrigation	100	80	80	95	100	100	80	100	80	0	0	100	100
Diversification and new varieties	100	50	100	100	80	80	40	50	100	50	80	80	100
Mixed Farming	80	40	90	80	80	70	60	80	90	20	20	100	70
Value addition	100	80	100	100	90	100	100	100	80	10	100	100	100
ISFM	80	60	80	85	85	100	80	100	90	10	100	100	100

	Costs		Benefits											
			Economic				Social			Environmental			Climate related	
	Capital Cost	Maintenance and operation	Income	Profit	Increase in Livelihood options	Gender	Employement	Education/Training	Poverty reduction pontential	Potential to reduce pensticide	Reduce waste of agricultural produce	Improved environmental sustainability	Resilience to Climate change	
Improved Storage	100	70	100	100	100	100	70	50	100	20	100	100	100	
Ecological Pest Management	100	0	70	90	60	70	60	100	70	100	100	100	60	
Irrigation	100	80	80	95	100	100	80	100	80	0	0	100	100	
Diversification and new varieties	100	50	100	100	80	80	40	50	100	50	80	80	100	
Mixed Farming	80	40	90	80	80	70	60	80	90	20	20	100	70	
Value addition	100	80	100	100	90	100	100	100	80	10	100	100	100	
ISFM	80	60	80	85	85	100	80	100	90	10	100	100	100	
Criterion weight	10	6	6	7	10	10	7	3	10	3	10	10	8	100

	Costs		Benefits											Total score
			Economic				Social			Environmental			Climate related	
	Capital Cost	Maintenance and operation	Income	Profit	Increase in Livelihood options	FALSE	Employement	Education/Training	Poverty reduction pontential	Potential to reduce pensticide	Reduce waste of agricultural produce	Improved environmental sustainability	Resilience to Climate change	
Improved Storage	1000	420	600	700	1000	100	490	150	1000	60	1000	1000	800	8320
Ecological Pest Management	1000	0	420	630	600	70	420	300	700	300	1000	1000	480	6920
Irrigation	1000	480	480	665	1000	100	560	300	800	0	0	1000	800	7185
Diversification and new varieties	1000	300	600	700	800	80	280	150	1000	150	800	800	800	7460
Mixed Farming	800	240	540	560	800	70	420	240	900	60	200	1000	560	6390
Value addition	1000	480	600	700	900	100	700	300	800	30	1000	1000	800	8410
ISFM	800	360	480	595	850	100	560	300	900	30	1000	1000	800	7775
						0								
Criterion weight	10	6	6	7	10	10	7	3	10	3	10	10	8	100

Annex III: List of Stakeholders

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